Sky and TELESCOPE

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The Baker-Nunn Satellite-Tracking Camera

Amateurs Photograph the Lunar Eclipse

The Hydrogen Spheres in Cygnus

American Astronomers Report

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★

Vol. XVI, No. 3

JANUARY, 1957

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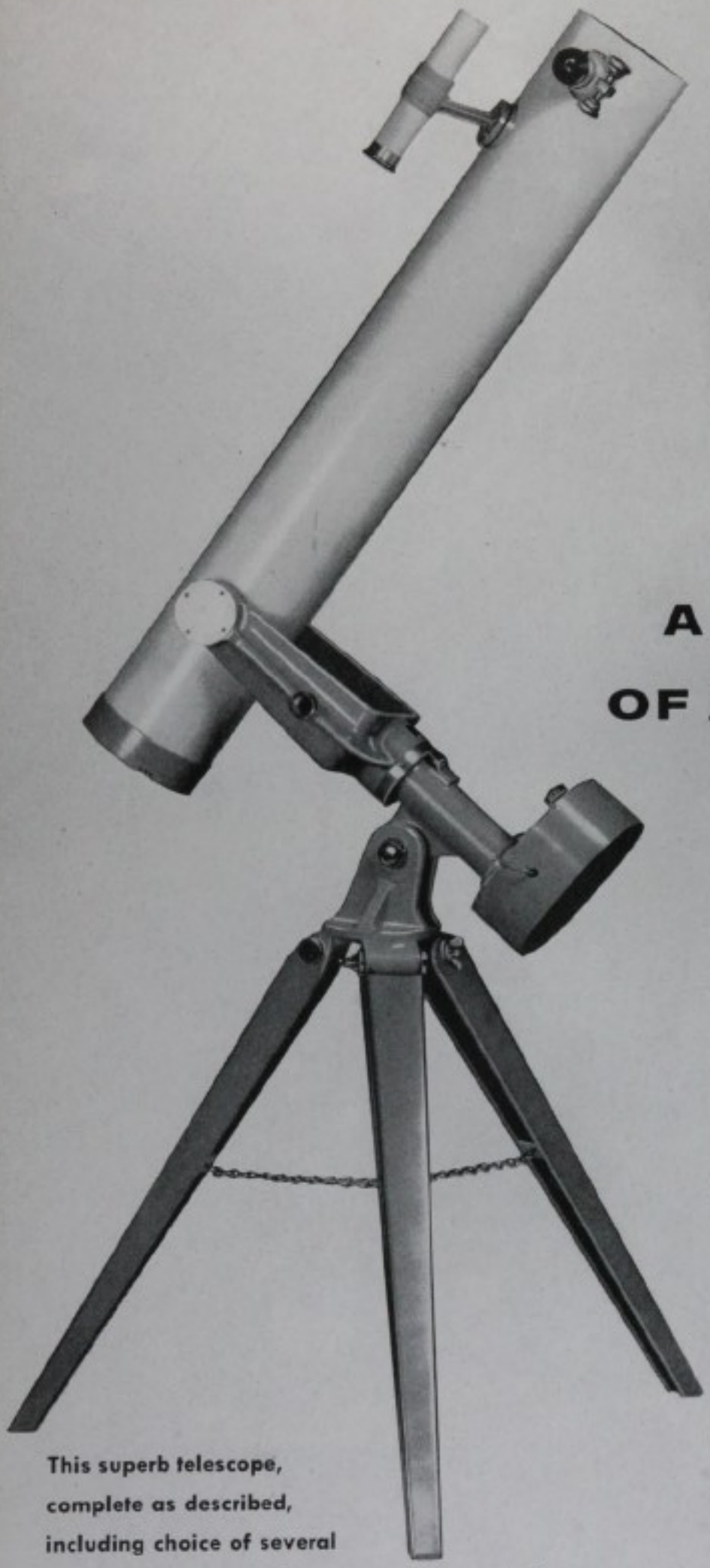

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COVER: This sketch depicts one of the fast Schmidt-type cameras that will be used for precise photographic tracking of artificial satellites during the International Geophysical Year. Its optics have been designed by James G. Baker and its mechanical features by Joseph Nunn. Twelve of these 20-inch-aperture f/1 instruments will be operated in many parts of the world by the Smithsonian Astrophysical Observatory, under the immediate supervision of Karl G. Henize. (See page 108.)

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FEATURE PICTURE: The Milky Way in Cygnus, from a mosaic of photographs in red light taken with the 48-inch Schmidt telescope on Palomar Mountain. Nebulosities bright and dark overlie great star clouds in this spectacular view of the Northern Cross and its surroundings. Copyright National Geographic-Palomar Observatory Sky Survey. (See page 118.) ..... Center

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The principal articles are indexed in THE READERS' GUIDE TO PERIODICAL LITERATURE.

Sky Survey by 48-inch Schmidt Camera Completed

FOR SEVEN YEARS, practically the entire observing time of the 48-inch Schmidt camera has been occupied with the sky survey financed by the National Geographic Society. Beginning in July, 1949, the whole sky accessible from Palomar Mountain (north of declination −27°) has been photographed in red and blue light, requiring 879 plates in each color. The plates are each 14 by 14 inches square. The blue photographs have a limiting magnitude of 21.1, the red plates reach 20.0. A mosaic of the latter in the Cygnus region is printed in the center of this issue, and is described on page 118.

In his annual report, published in the *Astronomical Journal* for October, 1956, Dr. Ira S. Bowen, director of Mount Wilson and Palomar Observatories, notes that this survey penetrates roughly three times farther into space than any previous coverage of the whole sky; the volume of space is over 25 times larger than in any previous atlas.

The plates were taken by Dr. Albert G. Wilson, now director of Lowell Observatory, George O. Abell, and R. G. Harrington. Since prints had to meet high standards to be included in the atlas, many fields were rephotographed, to replace plates rejected because of poor seeing conditions, errors in guiding, poor focus, or emulsion defects. For some fields more than one pair of acceptable plates were obtained. By July 1, 1953, the pairs of plates taken for the survey totaled 755, of which 338 were acceptable; at the completion of the observations in 1956 a total of 1606 pairs had been exposed, and 894 were graded as acceptable.

The graphic arts department of California Institute of Technology is busy printing copies of the atlas to fill orders from 42 institutions in the United States and 56 abroad.

Dr. Bowen points out the enormous mass of research material embodied in the atlas plates: "Many decades will be required fully to exploit them. Already a rapid qualitative survey of the plates has noted many new objects including 4 unusual asteroids whose orbits pass close to that of the earth, 11 comets, 13 globular clusters and 82 planetary nebulae. Four new dwarf members of our local group of galaxies have also been discovered . . . . In a special search of the plates Mr. Abell has found and listed the positions of about 2700 very rich clusters of galaxies thereby increasing manyfold the number of known objects of this type. The statistics of the size and distribution of these clusters is of great importance since they are the largest known structures in the universe . . . ."

The Baker-Nunn Satellite-Tracking Camera

KARL G. HENIZE, *Smithsonian Astrophysical Observatory*

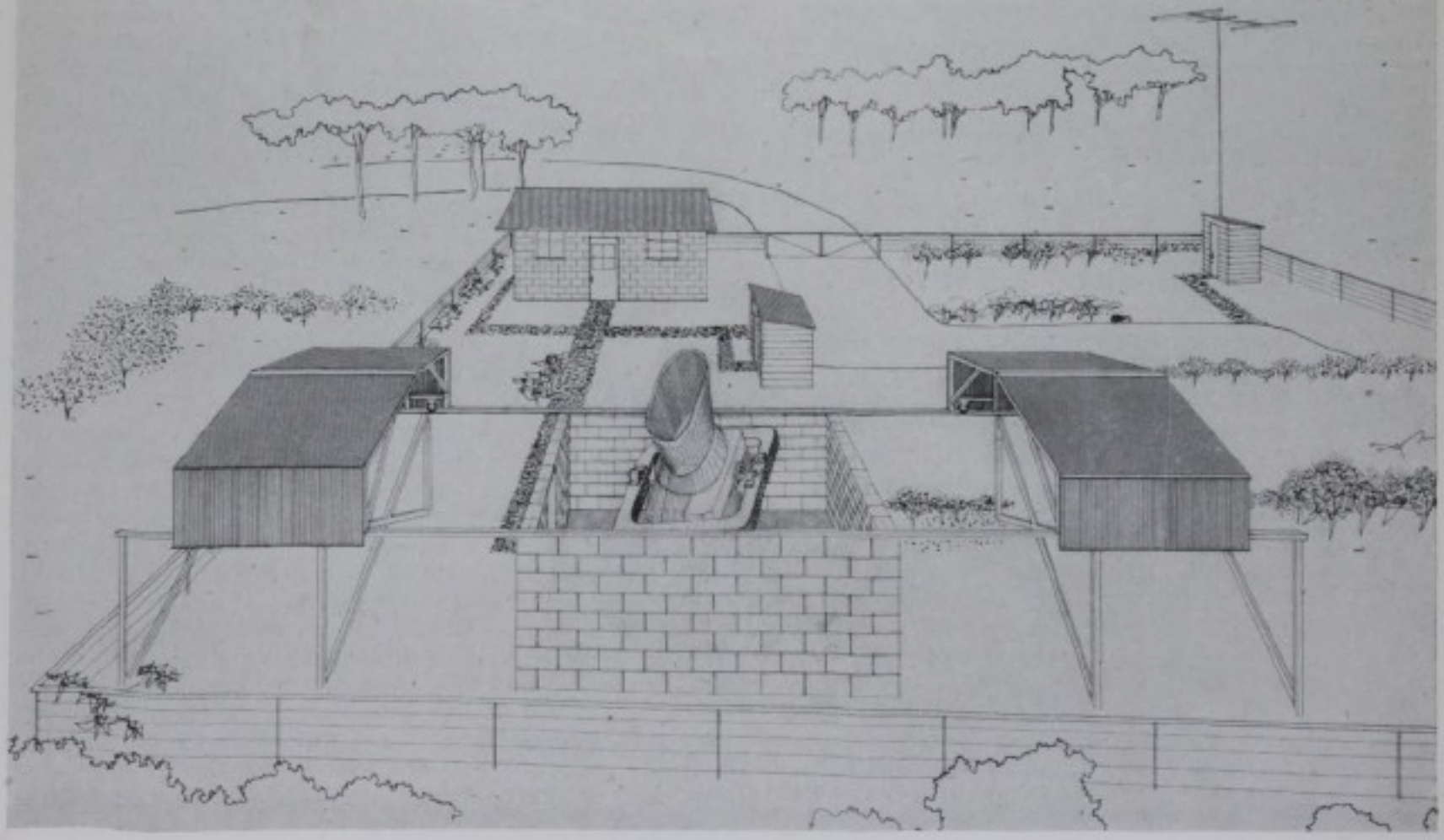
IN THE FALL of 1957, the first earth satellite of the International Geophysical Year is scheduled to be launched, in what is commonly called "man's initial step toward the exploration of interplanetary space." But paradoxically, astronomers will use the first earth satellites principally for studying the earth itself, not interplanetary space.

Why is this? Because, once a satellite is in free flight, its motion and orbit are determined by the gravitational field of the earth and by the density of the upper atmosphere. In the course of days, the orbit and motion will slowly change, and these changes will provide accurate measures of important geophysical quantities. For instance, the tenuous gases of the atmosphere at the height of the satellite orbit will impede the motion of the satellite and cause it to spiral slowly inward toward the earth. The rate of spiraling will indicate the density of the upper atmosphere.

As another example, if the earth were a perfect sphere the satellite orbit would maintain a constant orientation in space, but since the earth is slightly flattened the plane of the orbit will slowly turn, or precess, in the same way that a toy gyroscope precesses. The rate of precession will provide a measure of the amount of the earth's flattening. Other quantities that may be measured by orbit changes are the radial distribution of mass inside the earth and unevenness of mass distribution within the earth's crust.

The satellite will also provide important geodetic information. The nearly perfect great circle that the satellite orbit traces over the earth's surface will provide a hitherto unmatched reference plane for the measurement of precise geodetic positions at widely separated geographical points. With the Baker-Nunn satellite-tracking camera, which is the subject of this article (see front-cover drawing), the position of the satellite can be measured to within two seconds of arc. Taking into account several factors, some of which are not yet well known, the position of each observing station will be determined to about 30 feet. Thus, the distance between two stations, which may be on different continents, will be measured to about this accuracy—nearly 10 times better than that of present measures of transoceanic distances.

There are three distinct phases in the IGY satellite-tracking project. First, Minitrack stations will receive radio signals from a small battery-powered transmitter in the satellite. Next, MOONWATCH teams will use low-power wide-field telescopes for visual tracking. And, finally, precision photographic tracking will be accomplished by a dozen Baker-Nunn cameras. The radio-tracking program is administered by the Naval Research Laboratory, while the latter two programs are the responsibility of the Smithsonian Astrophysical Observatory, under the supervision of its director, Dr. Fred L. Whipple, and Dr. J. Allen Hynek, associate director, in charge of the satellite-tracking program. These two men were responsible for the general plans for the satellite-tracking cameras.



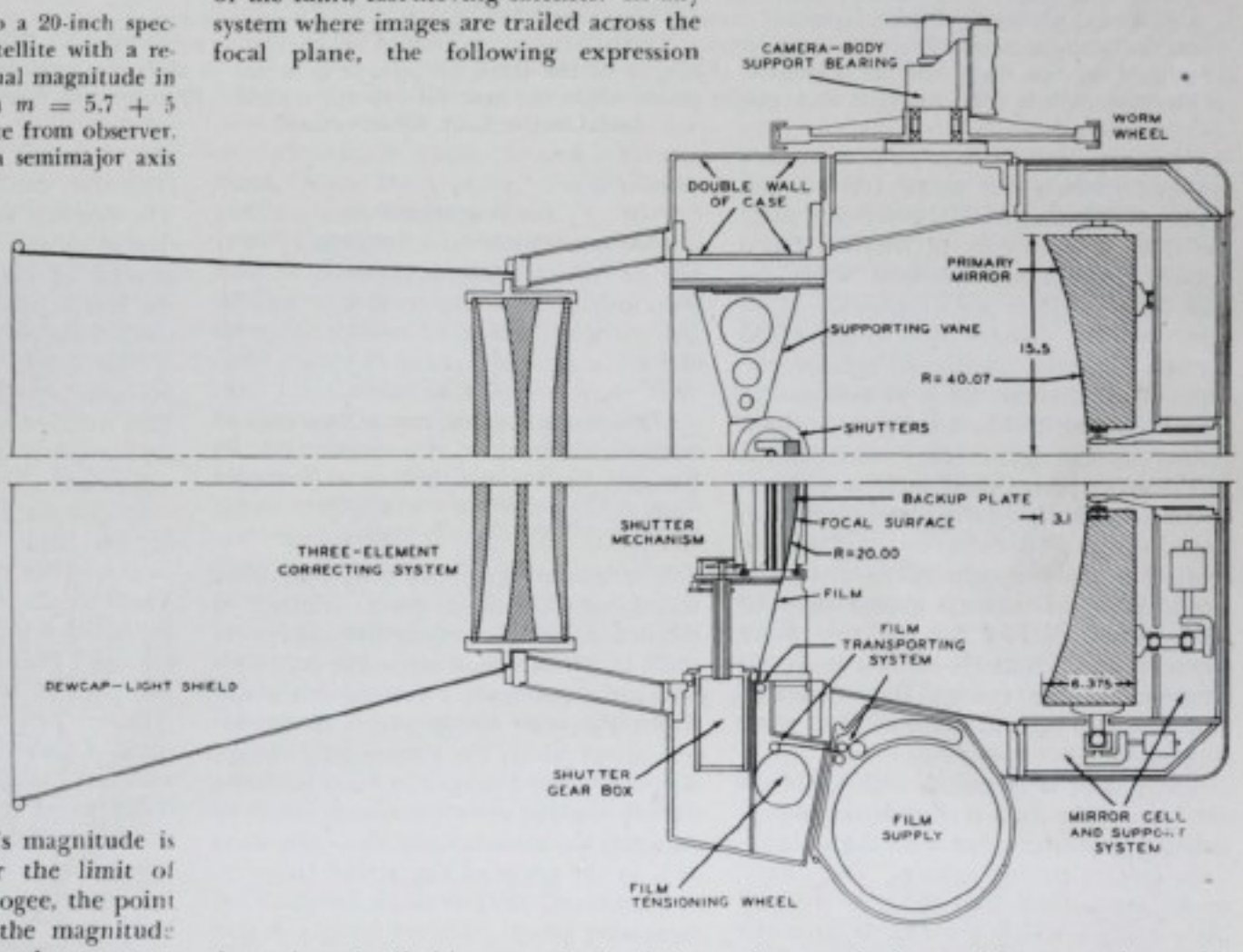
An artist's conception of the layout for a typical satellite-tracking camera station. In the foreground, the camera is seen in observing position. The roof of the camera shelter, which measures 14 by 14 feet, divides into two parts. These slide far apart so there is no obstruction to quick pointing of the camera in any direction. In the background is the combined office-shop and a power shack; in the upper right is the radio antenna, just behind a small fuel-storage building. Smithsonian Astrophysical Observatory drawing by Naibu Akashi.

The table gives data on the two characteristics of a satellite that affect the tracking problem: apparent brightness expressed as stellar magnitude, and angular velocity relative to the observer. Both depend on the height of the satellite above the earth's surface; the table is computed on the assumption that the orbit carries the satellite from 200 to 1,500 miles high.

At perigee, the point in the orbit near-

Height (miles)	*Photovisual Mag.*	*Orbital Velocity* (km./sec.)	*Angular Velocity* ('/sec.)
200	5.7	8.2	88
400	7.2	7.9	42
600	8.1	7.6	27
800	8.7	7.3	19
1,000	9.2	7.0	15
1,200	9.6	6.7	12
1,500	10.1	6.3	9

The table above applies to a 20-inch specularly reflecting spherical satellite with a reflectivity of 0.6. Its photovisual magnitude in the zenith is computed from $m = 5.7 + 5 \log d/200$, where d is distance from observer. The orbit is taken to have a semimajor axis of 4,810 miles.



Two cross sections of the Baker-Nunn satellite-tracking camera, showing the film-transport and shutter mechanism. The two halves are at right angles to each other, and all dimensions are in inches. The double-walled camera case is in sections (right to left), one holding the mirror, the next the support trunnions, the next the focal surface and film-transport system, and the last the three-element Schmidt correcting plate.

est the earth, the satellite's magnitude is expected to be 5.7, near the limit of naked-eye visibility. At apogee, the point farthest from the earth, the magnitude will be about 10. These values assume that the satellite is observed in the zenith, but, away from the zenith, it will lie at a greater distance from the observer and will be fainter. At a zenith angle of about 50 degrees, this reduction in brightness amounts to one magnitude. As for the angular velocity, it will vary from nearly 1½ degrees per second at perigee to about one tenth that value at apogee.

What are the general requirements of an optical system designed for tracking such an object? Field of view, focal length, and optical speed are of prime importance.

Since it is not expected that the predicted positions for such a rapidly moving object will be more accurate than about one degree, we will need a field of view at least five degrees wide, and it is desirable to have an even greater field along the direction of motion. The image quality must be of uniform excellence over the entire field in order to maintain the optical speed of the system; thus it is clear that a Schmidt system or modification of it is required. The Baker-Nunn camera has a field of 5 by 30 degrees, which is photographed on a strip of 55-mm. Cinemascope film about one foot long.

In order to achieve a measuring accuracy of two seconds of arc, it is necessary to have a focal length of 16 inches or greater. Since significantly longer focal lengths would make the tracking camera unwieldy, a value of 20 inches has been selected. This focal length gives a film scale of 406 seconds of arc per millimeter.

The most difficult problem is to obtain sufficient optical speed to record an image of the faint, fast-moving satellite. In any system where images are trailed across the focal plane, the following expression determines the limiting magnitude of the trails:

$$\frac{\omega}{L} = \frac{3.438}{E} k \frac{A^2}{Fd}.$$

Here ω is the angular velocity in minutes of arc per second; L is the illumination in meter-candles cast by the satellite on the earth's surface; E is the exposure in meter-candle-seconds required to produce a "usable image" on a given emulsion (the term "usable" is open to wide interpretation, but for our purposes a value of 0.003 meter-candle-seconds seems reasonable for the fastest emulsions now available). Also, k is the transmission coefficient of the system, which accounts for blockage of the incoming light beam by the photographic film and shutter mechanism, as well as for losses due to reflection and absorption, and is taken as about 0.5 for the satellite-tracking camera; A is the aperture of the correcting plate of the Schmidt system; F is the focal length; and d is the diameter of the image spot (A, F, and d are in millimeters).

The above expression shows that the optical speed for a trailing image is directly proportional to the square of the aperture and inversely proportional to the focal length and also to the image diameter. Under the present requirements, the focal ratio can hardly be slower than f/1.0, which would require an aperture of at least 20 inches. (A focal ratio much faster than f/1.0 would lead to grave design difficulties.) If we substitute these values for F and A, together with the perigee values of ω and L, we may calculate the image diameter that is necessary to photograph the satellite at perigee with the camera held stationary. This is the practical lower limit for the optical speed, because even when the camera is made to track the satellite it is still necessary to record the trails of background stars at least down to the 5th magnitude.

The required image diameter is 0.030 millimeter, or 30 microns. Although this performance is not too difficult to achieve on the optical axis, at the edge of a 30-degree field it is nearly 50 times that of a classical f/1.0 Schmidt. The problem of providing such excellence of performance was given to Dr. James G. Baker, of Spica, Inc., who is well known for his design of many novel astronomical instruments, such as the famous super-Schmidt meteor cameras.

He designed the optical system shown

Three examples from astronomical photography illustrate some of the principles of observing the satellite. At the left is a Harvard photograph of a Geminid meteor whose trail has breaks caused by a rotating shutter in the camera; the meteor's motion can be measured from these breaks. In the center, the trail of an asteroid is recorded on a long-exposure photograph guided on the stars, but for a fainter object, as in the third picture, it is better to shift the camera to follow the moving asteroid, which then appears as a bright point while the star images are trailed. Photographs from Harvard Observatory and Goethe Link Observatory.

in the drawing on page 109 of the principal camera parts. Its correcting plate has three components, of which the two outside surfaces are spherical while the four inner surfaces are aspherical. However, only two distinct types of aspherical surfaces must be produced, because the first and fourth are alike, as well as the second and third. These components have greater optical power than the classical Schmidt correcting plate and, as a consequence, considerable chromatic aberration would occur. To overcome this and to achieve a truly apochromatic system, a combination of unusual glasses must be used: Schott KzFS-2 for the two outer elements and Schott SK-14 for the central element. These reduce the chromatic aberration to zero at three distinct wave lengths.

The mirror is spherical, with a 31-inch diameter. The focal surface has a 20-inch radius of curvature, but with slight deviations from a perfect sphere. These deviations are figured into the glass backup plate against which the film is stretched during an exposure.

A detailed ray-tracing analysis has been made for this system by Dr. Baker, who finds that 80 per cent of the light from ultraviolet to deep red is focused into a 20-micron circle of confusion (effective image diameter) at all points in a 30-degree field.

In operation, the telescope's motion will track the satellite with an accuracy of one per cent, thereby increasing the effective exposure time ideally by a factor of 100 and the limiting magnitude by five magnitudes. The table shows the limiting magnitudes when the camera is stationary and when it is tracking. It is seen that under the most difficult circumstances, when the satellite is at apogee, its brightness will be about three magnitudes above the film limit.

Angular Velocity ('/sec.)	*Limiting Magnitude*		*Satellite Mag.*
	Stationary	*Tracking*	
87.8	5.8	10.8	5.7
42.1	6.6	11.6	7.2
19.4	7.4	12.4	8.7
8.9	8.3	13.3	10.1
0.25*	12.2	17.2	—

*This is the sidereal rate at the celestial equator. In this table, it is assumed that 80 per cent of the light falls in a 30-micron image. The satellite-tracking camera is expected to achieve this efficiency.

The mounting of the telescope, illustrated on the front cover, consists of three axes which permit the camera to track in any direction across the sky. Two axes are altazimuth: a vertical one about which the yoke swings and a horizontal one about which the gimbal ring swings. These axes are clamped in fixed positions during tracking, which is accomplished by swinging the camera body about the third axis, in the plane of the gimbal ring.

Traditional astronomical methods of measuring image positions relative to star images on the film will be a necessity in order to achieve the precision of two seconds of arc. But, if we track on the satellite when it is at perigee, the stars must trail and only those brighter than magnitude about 5.8 will be recorded. Fortunately, on the average two or three stars of this brightness will fall in the 5-by-30-degree field. If we must measure across several inches of film, however, from the star image to the satellite image, stretching of the film and distortion of the emulsion will introduce greater errors than can be tolerated.

To avoid these pitfalls, it is planned to cause the camera to oscillate so that it will alternately track at the satellite rate and at the rate of sidereal motion parallel to the satellite orbit. In this way exposures on the satellite and on the background of faint stars can be made on a single film. The satellite can then be measured relative to nearby star images. We can take account of the satellite motion between the two exposures by measuring the distance between the "star-exposure" images of the bright stars and the "satellite-exposure" images of these same stars. This distance will never exceed one inch; the problem of film stretching is thus minimized.

It is important to provide sharp breaks in the trail as reference points for measurement and for time determination. These breaks will be produced by a rotating barrel shutter with all but two "staves" missing. This shutter is shown in the upper part of the camera diagram as the cylinder that encloses the film backup plate. Concentric with the barrel shutter and just outside it is a clamshell shutter which snaps open and shut to begin and terminate each exposure.

We may describe the operation of the satellite-tracking camera in terms of a basic cycle in which the tracking rate varies from sidereal to satellite and back again. The length of this operating cycle may be set at 2, 4, 8, 16, or 32 seconds. If we begin the cycle just at the end of the star exposure, the following events occur in the order given:

The tracking rate accelerates until the satellite rate is reached. The clamshell shutter snaps open for an interval of 0.1 cycle, during which the exposure is chopped into four segments by the continuously rotating barrel shutter (which turns 20 times per cycle). At the instant of some one chop, a stroboscopic flash illuminates the time-display unit attached to the camera and the time is photographed on the following strip of film through a small auxiliary optical system. After the clamshell closes, the tracking rate decelerates to the sidereal rate and the clamshell

opens again for 0.1 cycle. This star exposure is likewise chopped into four segments but the time is not recorded. After the shutter closes again, the film is automatically changed and the cycle repeats.

Power for these operations is delivered by two ¼-horsepower synchronous motors. One motor drives the camera at a constant rate. The other drives the oscillating motion, the shutter rotation, the film-transport mechanism, and the stroboscope firing trigger, all of which are connected by a direct mechanical linkage.

The settings of the mean tracking rate and of the amplitude of oscillation are continuously variable and may be made with an accuracy of one per cent. To achieve this, ingenious design must be combined with precision machine work. The design of the mounting, tube, drives, and other mechanical parts of the Baker-Nunn camera is the work of Joseph Nunn, Los Angeles, California.

At its greatest angular velocity, the satellite will move some 5,300 seconds of arc per second of time. A measuring accuracy of two seconds of arc along the direction of motion would thus require time determination to 1/2,500 second of time in this extreme case. It is impossible to achieve this precision in field operations but, clearly, we must strive for the greatest possible accuracy. The main component of the time unit installed with each telescope will be the Model 111 crystal clock manufactured by Ernst Norrman Laboratories, Williams Bay, Wisconsin. Modifications and additions to this basic unit have been made chiefly by Robert J. Davis at Harvard Observatory.

The main additions are a radio receiver for WWV time signals, a system of time presentation readable to 1/10,000 second, and a "slave" clock that will duplicate the time presentation within the body of the telescope where it can be photographed during every operating cycle. The time presentation includes a rotating dial for 1/100 second, and an amplitude-modulated circular-sweep oscilloscope which can be read to 1/10,000 second. This will display the 10-kilocycle output of the clock and compare it with the signal received from WWV. If daily comparison with WWV can be made, the error of this time system may be held to 1/1,000 second. In the "slave" clock, which is a miniature duplicate of this time presentation, it is necessary to fire the stroboscopic flash and to admit a brief pulse to the oscilloscope once during each camera cycle. E. A. Halbach, of Milwaukee, Wisconsin, assisted in the design of the "slave" clock.

The satellite-tracking cameras and the timing equipment are now under construction. The basic contractors are Perkin-Elmer Corporation, Norwalk, Connecticut, which is producing the optical components, and Boller and Chivens, Inc., South Pasadena, California, which is making the mechanical components. The crystal clocks and their accessories are being built by the Norrman Laboratories. The correcting-plate glass is being produced by the Schott optical glass works in West Germany, while the mirror blanks are coming from the Corning Glass Works, Corning, New York. Several mirror blanks have already been delivered, and the first glass from Germany is expected this month. The first optical system and its camera body and mount are all expected by early July.

This first camera will be erected at the prototype satellite-tracking station at White Sands, New Mexico, where it will be subjected to intensive shakedown trials. The remaining cameras, to be delivered at the rate of one per month, will be erected at tracking stations scattered over the globe. Sites that have been selected include central Florida; Mauna Loa Observatory, Hawaii (see page 116); Tokyo Observatory, Tokyo, Japan; central Australia; Curacao, Netherlands West Indies; Boyden Observatory, Bloemfontein, South Africa. Other sites being considered include Cadiz, Spain; Teheran, Iran; Dehra Dun, India; Cordoba, Argentina; and Arequipa, Peru.

It is estimated that each station will be able to photograph the satellite on the average of at least once a week. Not only must the station be located near the satellite's path in order to make an observation, but it must be in the twilight zone at the same time. Several hours before the expected transit, the latest data on the orbit will be radioed to the station, giving the settings of the yoke, the gimbal ring, and the camera, the brightness of the satellite, its angular velocity, and the moment when tracking must begin. Appropriate settings will be made on the telescope and, at the appointed instant, the tracking mechanism will be engaged. Subsequent operation of the camera will be automatic.

Between 10 and 100 separate photographs of the satellite may be made during each transit, depending on the particular circumstances. These photographs will be developed immediately and a rough position for the satellite will be measured, for transmission to the computing center in Cambridge, Massachusetts, where it will be used in improving the predictions of the satellite's flight. The film itself will be shipped to the computing center for high-precision measurement. After observations of all the IGY satellites have been completed, these precision measures from all stations will be combined in the solution of complex orbit equations to yield the geophysical and geodetic data mentioned at the beginning of this article.

NOTE: Personnel to man the optical tracking stations discussed in this article already are being recruited. These men must be reliable and resourceful, and should have at least an elementary knowledge of astronomy. Preference will be given to applicants with practical experience in telescope operation, in maintenance and repair of mechanical instruments and electronics equipment. Interested persons should submit their qualifications to Satellite-Tracking Program, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge 38, Mass.

YERKES OBSERVATORY LOSES NIGHT ENGINEER

Frank Sullivan, for many years the night engineer at the 40-inch telescope of Yerkes Observatory, passed away on November 10, 1956, after a short illness. He was born in 1873. His interest in astronomy was stimulated by J. A. Parkhurst.

More than two generations of astronomers, working at the world's largest refractor during the first half of this century, have had the assistance of indefatigable Mr. Sullivan. The observers would change shifts during the night, but their helper would remain from sundown to sunup in his unselfish devotion to observational astronomy.

LETTERS

Sir:

At the recent Western Amateur Astronomers convention in Flagstaff, I heard a paper by Eugene Lahr, "Micrometeorites in Your Own Back Yard." But the subject of the paper was meteoritic dust and not micrometeorites. The latter term has been definitely defined by Fred L. Whipple as designating "an extraterrestrial body that is sufficiently small to enter the earth's atmosphere without being damaged by encounter with the atmosphere."

In 1950, John D. Buddhue published an extensive monograph on meteoritic dust, with a bibliography of 108 papers. I have myself been interested in the problem for more than 30 years. I collected meteoritic dust during the 1930's, by a number of methods, but the best one was to trap the magnetic dust washed from tile roofs by placing magnets, wrapped in plastic bags, at the exits from downspouts. This work was reported in a short paper in *Scientific Monthly* in 1940.

At that time I proposed establishing a collecting station on a coral island, remote from exposures of igneous rocks, where regular collections could be made and studied for a year or longer. The plan was to erect a noncorrosive roof from which all drainage would pass through traps. Thus, magnetic and nonmagnetic solids alike could be removed and studied. Rain washings would be supplemented by spraying the roof, to make the catch more regular and to provide special washings for meteor showers. It was also suggested stations be set up at different latitudes.

Such a program would be ideal for the International Geophysical Year.

H. H. NININGER
American Meteorite Museum
P. O. Box 146, Sedona, Ariz.

The first half of the November 17-18, 1956, total eclipse of the moon, photographed by Hal Swiggett, at San Antonio, Texas, with a 4 x 5 Speed Graphic camera, 127-mm. lens, and Royal Pan film. The exposures were at 10-minute intervals, starting at 11:10 p.m. CST at the left. He began with 1/400 second, f/11, and used one second, f/5.6, for the last exposure, when the moon was in total eclipse. On the facing page, a similar series by George Trotzuk shows the later stages of this eclipse.

Amateurs Photograph the Lunar Eclipse

Left: At about 11:00 p.m. PST, William Shopes took this picture of the totally eclipsed moon and the Pleiades, using the 4-inch Zeiss camera at Leuschner Observatory, Berkeley, California. The picture was transmitted by Michael Golub.

Right: At Henderson, Texas, Kenneth Wagland (left) used a 4-inch reflector to photograph the eclipse (see series on opposite page), with Billy McMurray and Jimmy Hudson.

Don Strittmatter, Tucson, Arizona, used his 8-inch Newtonian reflector and projection through an eyepiece to obtain images of the moon nearly 2½ inches in diameter. From right to left, the times of these pictures of the partial eclipse were 10:20, 10:30, and 10:40 p.m. MST. The shape and large size of the earth's umbral shadow are well illustrated by this series and the photographs by K. E. McCorkle on page 114.

Above: The moon emerging from eclipse was recorded by George Trotzuk, Detroit, Michigan, with a Speed Graphic and an f/3.7 105-mm. lens, using the exposure guide from the November "Sky and Telescope" (page 43). The film was Tri-X, developed in Microdol. The first exposure was made at 2:40 a.m. EST, 13 minutes after totality ended; the intervals between exposures were all 10 minutes. In the last two pictures, the moon is only in the penumbral shadow.

Right: With his home-mounted 4-inch reflector (seen on the facing page), Kenneth Wagland obtained these three pictures that illustrate the penumbral phases. The top exposure is the full moon before the event started; the second, at 10:35 p.m. CST, shows the penumbral shadow on the right, nearly half an hour before first umbral contact. In the bottom photograph, at 11:05, Tycho is deeply immersed in the penumbral shadow, about 17 minutes before this crater entered the umbra.

Below: The rapid brightening of the moon as it was coming out of the earth's shadow is illustrated by these four pictures, each of 1/100 second, at 1:39:08, 1:49:21, 2:00:28, and 2:18:44 a.m. CST. Harry and David Brown, at Columbia, Missouri, used a 10-inch f/9 reflector, stopped down to eight inches at the mirror. A 1½-inch image of the moon was formed by projection through an eyepiece. The film was Royal Pan.

Above: The moon was just about to enter the penumbra when K. E. McCorkle, Memphis, Tennessee, secured his first exposure at 10:00 p.m. CST; the other shots were at 10-minute intervals from 11:00 on. Mr. McCorkle's 6-inch f/5 reflector, hand guided, gave a 1.1-inch lunar image by projection through a 16.8-mm. Erfle eyepiece. Exposure times on Ilford HPS film ranged from 1/100 second at the start to 10 seconds for the last image. The development was in Ethol UFG for six minutes at 75° Fahrenheit.

Left: At Cactus Peak, California, E. C. Bruner, Jr., used a 3½-inch ship's telescope on a temporary mounting for eclipse photography. The camera had an f/1.8 lens, but is not shown here; it was removed from the telescope each time the moon was centered in the field.

Below: The great light loss suffered by the moon during eclipse is shown by the exposure times Lester Neufeld, of Corona Del Mar, California, used for these three pictures. The first, showing the moon at 8:07 p.m. PST, was 1/1,000 second. The middle image was obtained at 9:01, just before umbral eclipse began, exposure 1/500 second. The view at the right was during totality, at 10:10, and required 1½ seconds. All of Mr. Neufeld's photographs were taken on Tri-X film, at the prime focus of his 6-inch reflector of 64 inches focal length.

☆ ☆ *SKY AND TEACHER* ☆ ☆

Sponsored by the
Teachers' Committee of the American Astronomical Society

ASTRONOMY AS A SCOUT PROGRAM

DURING JANUARY, boy scouts and cubs scouts all over America will be studying astronomy. For many this will be their first encounter with the wonders and mysteries of the heavens; for others it will be a continuation of an interest which has already become rooted, and in many cases quite firmly established as a hobby. However, for both novices and the initiated the goal remains the same: to stimulate the boys' natural curiosity in this field, and to teach them accurate facts and scientific methods as opposed to pseudo-science and fiction.

Not the least of the many means to be employed in accomplishing this purpose is the amateur astronomer himself. For those who suddenly find themselves called upon to speak before a troop, and have had no previous experience of this type, the following suggestions may be of some help.

Topics for study should be chosen in accordance with the age group and the amount of former knowledge, but should include, in one lecture or separate talks, the following three themes:

A. Consellations and mythology; use of stars in direction finding.

B. The solar system.

C. Stars, space, and galaxies.

Topic A is an important one in scouting. Although most scouts can find the Big Dipper and the North Star, their knowledge of constellations is somewhat limited. This is especially true of scout troops located in urban areas where a good view of the sky is often impossible. Generally speaking, the boys would probably not be interested in an overdose of mythology, but a few colorful examples can be used to good advantage. Interest in constellation study can be aroused by emphasizing the importance of star identification for navigation, simple direction finding, and aid in the location of such interesting objects as planets, clusters, nebulae, and double stars.

To teach star identification to cub and scout groups, use a simple basis. A very successful method is the "key constellation" approach. In the January sky Orion may be selected as the key constellation, and can then be used as a guide for locating the brightest stars and constellations visible on a winter evening, as shown in the chart. When lecturing outdoors, a flashlight with a powerful beam makes an effective pointer.

Topic B, the solar system, is always popular with youthful groups. When studying this, the boys will want to know more than just sizes and distances. The instructor would do well to answer the following questions during his talk: Why are the planets different colors if they are all reflecting sunlight? What are the temperatures on the sun, moon, and planets? How many moons are there? What are the rings of Saturn made of? How fast do planets travel through space? What are sunspots? What are the northern lights? How many meteors enter our atmosphere each day? What are meteorites made of? How did the moon get its craters? What is the truth about space travel? If these questions, and many others like them, are not answered in a solar-system talk, the lecturer can be sure that a good many will pop up when the lecture is over. In any event, a question period is a lively way to end the session.

In dealing with topic C, the speaker will touch upon matters quite new to his listeners, particularly if they are of elementary school age. The Milky Way is not hard for youngsters to understand if it is compared to a blueberry pie, with our sun as just one small berry. Variable stars, eclipsing binaries, and bright and dark nebulosities are also well within the realm of a young boy's comprehension if explained in a simple and graphic manner. However, exterior galaxies, which may be studied in conjunction with a discussion of modern methods of research, are more readily understood and appreciated by older boys.

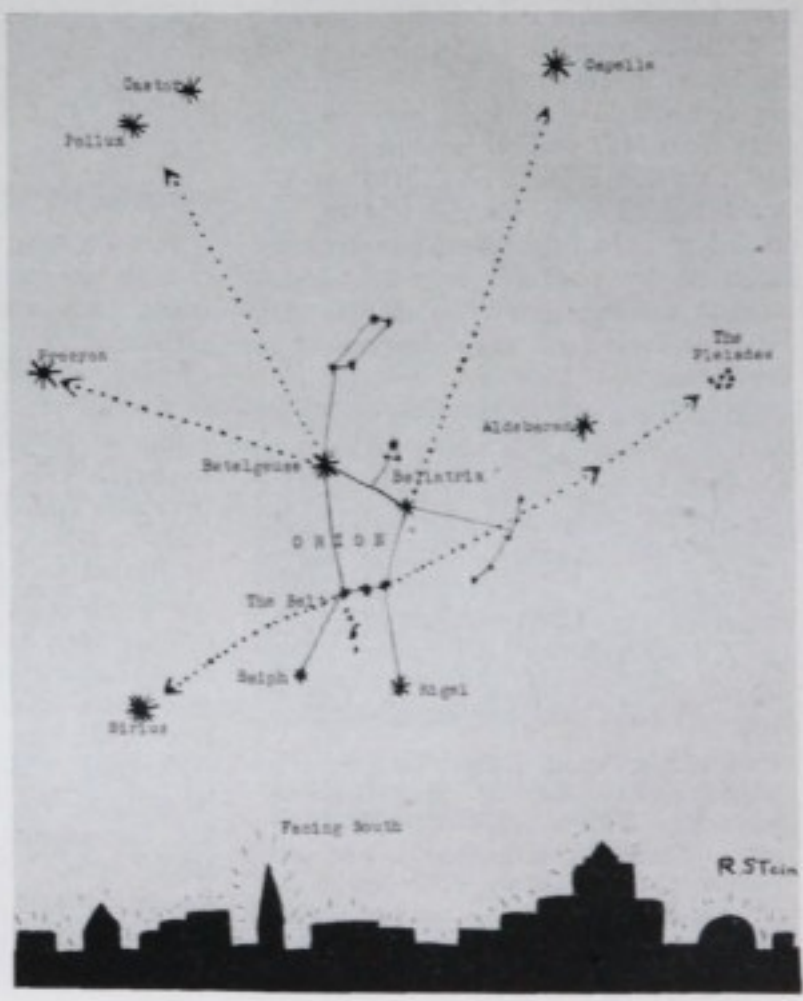
No matter what the type of group or lecture, visual material is invaluable. Slides, charts, photographs, models, and the blackboard can be used. The most obvious and useful aid is the telescope. Any scout group would enjoy and benefit from viewing the moon, planets, and Orion nebula on a crisp January evening. So the boys will have a clear understanding of what they are observing, and what they should especially look for, it is usually best to explain first what objects will be seen and their most interesting characteristics.

In addition to the talks, active participation by the boys themselves can round out their study of astronomy. Flashlights and tennis balls can be used to demonstrate eclipses; clay or plaster models can be constructed to show the solar system and its motions; oatmeal boxes can be made into miniature planetariums to project familiar constellations on the walls and ceilings of darkened rooms. Troops should also participate in local "sky hikes" to observe the stars and planets, and to test homemade astronomy gadgets, such as sundials, telescopes, and peloruses. For those fortunate enough to live near a planetarium or college observatory, a field trip of much educational value can be arranged in advance.

By these methods and many more, educators, troop leaders, and mindful amateurs will combine their efforts in January to help America's youth become better acquainted with our science, providing the groundwork for hours of astronomical enjoyment by thousands of individuals.

RAYMOND J. STEIN
Planetarium Supervisor
Newark Museum
Newark, N. J.

Right: This sketch illustrates the ease with which an attractive and informative chart may be made for constellation study by boy scouts.



Below: In this Newark Museum photograph, Boy Scout Larry Janesky is measuring the altitude of the sun with a homemade device.

NEWS NOTES

MAUNA LOA OBSERVATORY

A high-altitude observatory has been erected on the slope of the Hawaiian volcano Mauna Loa, at a cost of $25,000. Located at a warm and relatively accessible site 11,134 feet above sea level, but some 2,500 feet below the mountain's summit, the concrete-block structure contains five rooms, a tower, and a large open observing platform. Six observers may be accommodated at the observatory.

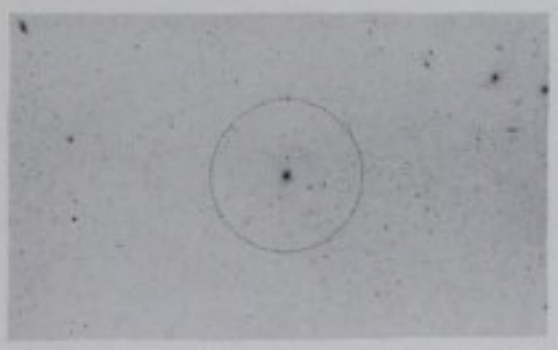
Operated jointly by the National Bureau of Standards and the U. S. Weather Bureau, the station will carry on studies of the upper atmosphere, long-range weather forecasting, cosmic rays, total solar radiation, snow crystals, the airglow, and similar subjects. During last summer, C. C. Kiess and C. H. Corliss studied the spectrum of Mars in a search for water vapor in that planet's atmosphere.

RADIO HALO AROUND GALAXY MESSIER 87

The bright elliptical galaxy M87, in the Virgo cluster, has been known for several years as a radio source. Now it is found to have an extensive halo of weaker radiation, from observations at a wave length of 3.7 meters. Such halos have already been detected surrounding our own Milky Way system as well as the neighbor galaxy, M31 in Andromeda.

Observations of M87 were made with the large radio telescope, at Cambridge, England, which combines interferometers of high resolving power (spacing 157 wave lengths) in an east-west direction and low resolving power (spacing 14 wave lengths) in a north-south direction. J. E. Baldwin and F. G. Smith have used the interferometers in an arrangement to give good discrimination between radiation from M87 and other sources. They find that the diameter of M87 in 3.7-meter radiation is 50 minutes of arc, much larger than the 3.3-minute diameter indicated by photographs. By varying antenna spacing, they were able to map the distribution of radio brightness in different zones of the halo. About one fifth of the total radio flux from M87 comes from this extended halo, the rest originating from the neighborhood of the galaxy itself.

This work is reported in the *Observatory*, August, 1956.



Part of the Virgo cluster of galaxies, photographed by D. W. Dewhirst with the 17-inch f/3.7 Schmidt camera at Cambridge, England. The circle surrounding Messier 87 has a diameter of 50 minutes of arc and shows the extent of the radio emission. Reproduced from the "Observatory."

BUHL PLANETARIUM ATTENDANCE RECORD

During the fiscal year that ended October 31, 1956, attendance at the Buhl Planetarium and Institute of Popular Science in Pittsburgh set a 15-year record, topping the 200,000 mark by 664 persons. This was an increase of 50,000 over the previous 12 months, and included 44,000 persons who saw the traditional Christmas sky show in December, 1955.

The planetarium carries out an extensive education program, in which schools of the area take an active part. Student-built exhibits are displayed at such events as the school science fair, the Latin festival, geography show, and Historama. Other activities include career weeks, evening classes, and the science congress, at which students present scientific papers.

JOHN EVERSHED DIES

The passing of John Evershed on November 17, 1956, at the age of 92, has removed a British founder of modern solar physics. He was director of Kodaikanal Observatory in India from 1911 to 1923. For his contributions to solar spectroscopy – and particularly his discovery of radial motions in sunspots – Evershed received the gold medal of the Royal Astronomical Society. He had been a member of the British Astronomical Association since its founding in 1890, and for a time was director of its spectroscopic section.

FORDHAM SOLAR FURNACE

For studying the behavior of matter at high temperatures, solar furnaces offer many advantages over conventional carbon-arc and induction furnaces, according to the chemist T. S. Laszlo, who is director of the high-temperature laboratory at Fordham University. He has constructed a furnace using a 60-inch parabolic searchlight mirror to collect the sun's radiation, by which test samples can be heated to 3,500° centigrade within a few seconds.

With such a device the risk of chemical contamination is greatly lessened, and there is no electromagnetic field to interfere with measurements of electrical properties. The test sample need not be inclosed in a container, so that measuring instruments can be placed conveniently near. The central part of Dr. Laszlo's mirror contains an observation hole in which an optical pyrometer is placed for temperature measurements.

ROTATION OF SATURN

On very rare occasions temporary spots appear on the planet Saturn that are suitable for determining its rotation period. Henri Camichel, Pic du Midi Observatory, France, has recently found a small and distinct white marking on two fine photographs of the planet taken February 11 and 14, 1946. His measurements of these plates give 10 hours, 21.4 minutes, for the sidereal rotation period of Saturn, with a probable error of only 0.5 minute, and −12°.3 for the spot's latitude.

Dr. Camichel's report in the *Bulletin Astronomique* also lists previous determinations of the length of the Saturnian day. It is shortest at the planet's equator, where the white spot of August, 1933, gave 10 hours, 13.6 minutes, but it is progressively longer at higher latitudes. In June, 1903, W. F. Denning found a period of 10 hours, 39 minutes, 21.1 seconds for a temporary spot in the north temperate zone.

CONFERENCE ON BINARY STARS

A three-day meeting of 21 astronomers from the United States and Canada was held at the Dominion Astrophysical Observatory, Victoria, B. C., last August. It was sponsored by the National Science Foundation. The purpose of the conference was to discuss astrometric, photometric, and spectroscopic observations of double stars. One of the five sessions dealt with theoretical aspects of the origin and evolution of binary systems. The papers presented at the Victoria conference will be published in the *Journal* of the Royal Astronomical Society of Canada.

"SPACEFLIGHT"

A new quarterly journal, *Spaceflight*, is being published by the British Interplanetary Society as a popular counterpart to its more technical *Journal*. Its editor is Patrick Moore, and the first issue is dated October, 1956. The principal article is by Kenneth W. Gatland, describing the Vanguard artificial satellite project. He presents a table of characteristics of high-performance rocket vehicles, including the three-stage rocket that is designed to carry the artificial satellite into its orbit.

SOLAR FURNACE SYMPOSIUM

A two-day symposium on solar furnaces will be held in Phoenix, Arizona, on January 21st and 22nd, at the Hotel Westward Ho. It will be conducted by the Association for Applied Solar Energy, in co-operation with Stanford Research Institute, the University of Arizona, and Arizona State College at Tempe. The technical discussions will concern solar furnaces that attain temperatures above 3,000° centigrade, and the use of small furnaces in basic and applied research. Further information may be obtained from John I. Yellott, 3424 N. Central Ave., Phoenix, Ariz.

Amateur Astronomers

Mountain States Region Added to Astronomical League

THE Astronomical League now contains nine regions within the United States, the newest being the Mountain Astronomical Research Society, which covers Colorado, Wyoming, Utah, Montana, and eastern Idaho. Four societies are included in the region. E. D. Onstott, 2421 Second Ave., Pueblo, Colo., is chairman of the section, and Kenneth Steinmetz, 1680 W. Hoye Place, Denver 23, Colo., is regional representative.

The league, which was founded in 1946, has more than 100 member societies with over 5,000 individuals, 27 members-at-large, two affiliate members, and seven supporting members.

The number of member societies in each region and its geographical extent are:

Great Lakes – 12 members
Indiana, Kentucky, Michigan, and Ohio.

Middle East – 11 members
Delaware, Maryland, southern New Jersey, Pennsylvania, Virginia, and West Virginia.

Mid-States – 8 members
Arkansas, Kansas, Missouri, and Oklahoma.

Mountain Astronomical Research Society – 4 members
Colorado, eastern Idaho, Montana, Utah, and Wyoming.

North Central – 15 members
Illinois, Iowa, Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin.

Northeast – 23 members
New England, northern New Jersey, and New York.

Northwest – 6 members
Western Idaho, Oregon, and Washington.

Southeast – 19 members
Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, and Tennessee.

Southwest – 9 members
Louisiana, New Mexico, and Texas.

JACKSONVILLE AMATEURS OFFER FILM ON THE MOON

The first release in a proposed series of films devoted to observational astronomy has been announced by the Jacksonville Amateur Astronomers Club. It is a 16-mm. sound motion picture entitled, Telescopic Observations, Volume I: The Moon. All the planning and production was carried out by members of the society, and they expect to use fees from the film's rental to produce others like it. They are currently working on the planets.

Telescopes and cameras used for the observations are shown in the film. The moon, from crescent to full phase, is presented at magnifications from 50x to 375x, through 8-inch and 16-inch Newtonian reflectors. As lunar features are mentioned in the narrative, flashes on the screen pinpoint their locations, so an audience is never in doubt as to the identification of a crater, mare, or mountain range.

There are no stills or lapse-time sequences—all lunar views are continuous motion pictures, giving a feeling of actual presence at the telescope. The photography, especially at the higher magnifications, is of exceptional clarity. There is no attempt to discuss space travel or a "trip to the moon," but the meteoritic impact theory of lunar craters is described in the closing portions of the film, which lasts 26 minutes.

Groups interested in renting the film, at $10.00 per showing, should communicate with John A. Ebel, Librarian, Jacksonville Amateur Astronomers Club, 345 E. Forsyth St., Jacksonville, Fla.

KANSAS CITY CONVENTION

The 1957 general convention of the Astronomical League will be held on Labor Day weekend, August 31-September 2, in Kansas City, Missouri. The host will be the Astronomy Club of Greater Kansas City, which has more than 150 members. The club president, Gene L. Tandy, national secretary of the league, is general chairman of convention arrangements.

The University of Kansas City, Linda Hall Library, Rockhurst College, Kansas City Museum, and Midwest Research Institute are some of the educational and technical institutions that are cooperating with the amateurs in making plans.

CHEYENNE, WYOMING

During the recent close approach of Mars, we published a notice in the *Wyoming State Tribune* inviting the public to view the planet through our 8-inch refractor. Approximately 100 persons attended over a period of five nights, and from this group the Cheyenne Amateur Astronomers was formed.

We have 15 adult members and about 10 interested juniors who will form an auxiliary club in the near future. Meetings are held on the first and third Thursdays of each month.

Since there are only three telescopes in this area, our first activity will be to set up a telescope making workshop. More information may be had from the undersigned.

MRS. PHYLLIS DORAN
2706 East 10th St.
Cheyenne, Wyo.

THIS MONTH'S MEETINGS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Jan. 18, Dr. F. T. Haddock, University of Michigan Observatory, "Bursts of Radio Waves from the Sun."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. Jan. 28, Ted F. Gangl, "The Relationship of Astronomy and Geology."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Jan. 15, Prof. Clarence R. Smith, "Problems of the Geophysical Year."

Louisville, Ky.: Louisville Astronomical Society, 8:30 p.m., University of Louisville, Natural Science building. Jan. 1, Dr. Walter Moore, University of Louisville, "Sunspots."

Madison, Wisc.: Madison Astronomical Society, 8 p.m., Washburn Observatory. Jan. 9, Dr. T. E. Houck, Washburn Observatory, "Associations of Stars in Our Milky Way."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Jan. 2, motion picture, Flight to Mars.

Santa Ana, Calif.: Orange County Amateur Astronomers, 7:30 p.m., home of Norman Jarvi, 630 S. Walnut, Anaheim. Jan. 4, Dr. Frank Halstead, Darling Observatory, "Nebulae."

Springfield, N. J.: Amateur Astronomical Society of Union County, 8 p.m., Regional High School. Jan. 25, Thomas D. Nicholson, Hayden Planetarium, "Satellite."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Jan. 5, Dr. Frank K. Edmondson, National Science Foundation, "Exploring the Milky Way."

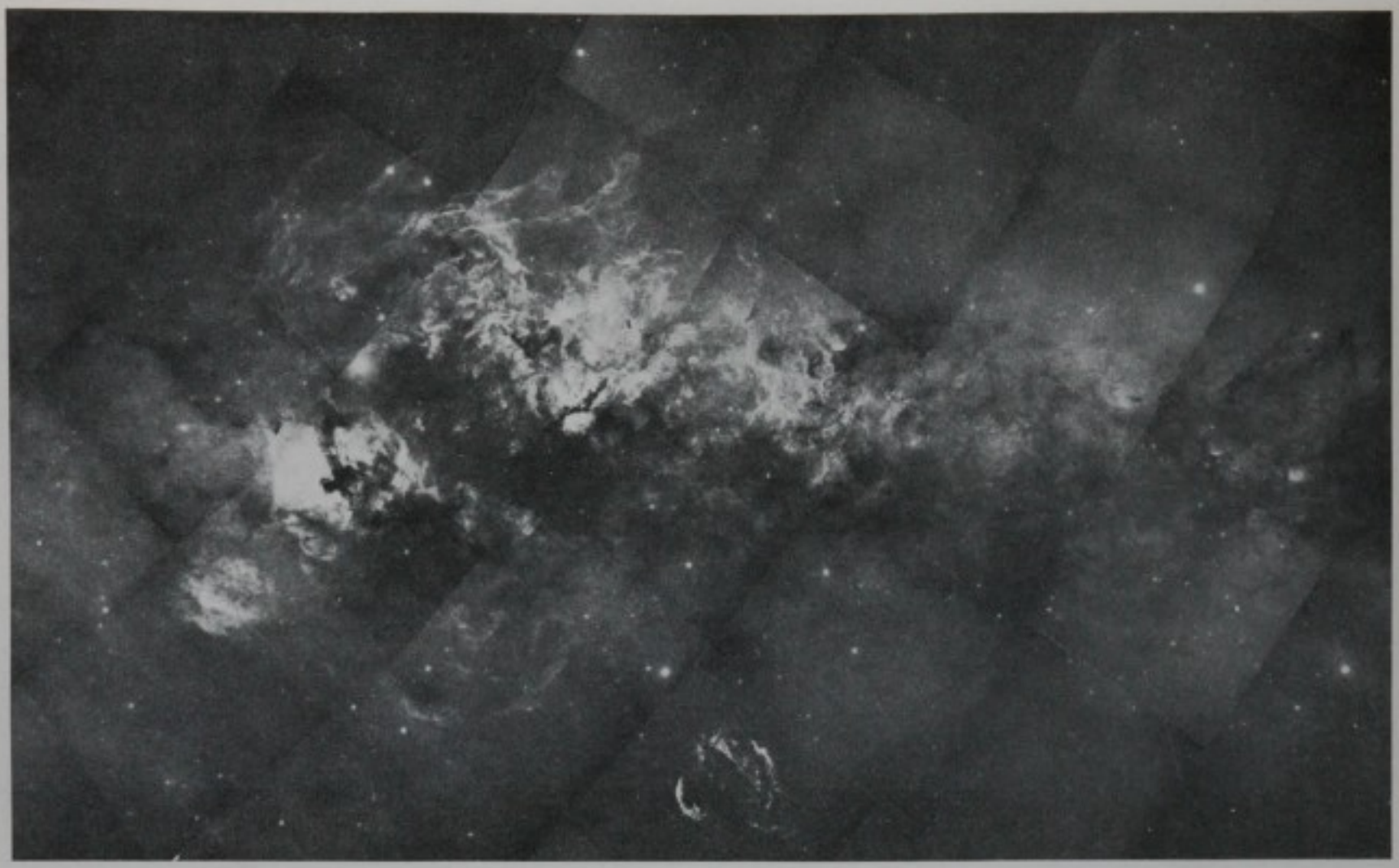
MILWAUKEE AMATEUR DIES

On November 13, 1956, Roy L. Dodd, one of Milwaukee's best-known amateur astronomers, died of a heart attack. He was 68 years old.

An electrical engineer by profession, Mr. Dodd was very active in civic programs, Masonic groups, the YMCA, and scouting. But his chief hobby was astronomy, which he practiced as a one-time president of the Milwaukee Astronomical Society and as chairman of the North Central Region of the Astronomical League at the time of his death.

INDIANAPOLIS, INDIANA

Each member of the Indiana Astronomical Society is being given a free ticket each month to a planetarium lecture at the Holcomb Planetarium and Observatory of Butler University, according to the society's monthly bulletin. The society has also volunteered to set up a station for observing artificial satellites.



The Milky Way in Cygnus and neighboring constellations, as photographed in red light by the 48-inch Schmidt camera at Palomar Observatory. The same view on a much-enlarged scale is on the center pages of this issue. The individual prints for the mosaic were prepared by James W. McClenahan, who also photographed the mosaic as a whole. Copyright National Geographic Society-Palomar Observatory Sky Survey.

The Hydrogen Spheres in Cygnus

OTTO STRUVE, *Leuschner Observatory, University of California*

A VISITOR entering the hall of the Astrophysical Laboratory at the California Institute of Technology, in Pasadena, is confronted by a striking photographic mosaic, 10 feet long and four feet high, of the Milky Way in Cygnus. It was assembled by Howard S. Gates, under the direction of Jesse L. Greenstein, from about 40 prints of plates taken with the 48-inch Schmidt telescope on Palomar Mountain.

The original photographs are each 14 by 14 inches, to a scale of 67 seconds of arc per millimeter, and are part of the well-known National Geographic sky survey carried out with the Schmidt telescope. The photographs of this survey are in pairs, 879 blue-sensitive and 879 red-sensitive plates. For the mosaic the red plates were used, as these show strikingly the red glow (hydrogen-alpha emission) of the immense gas clouds that abound in this part of the sky.

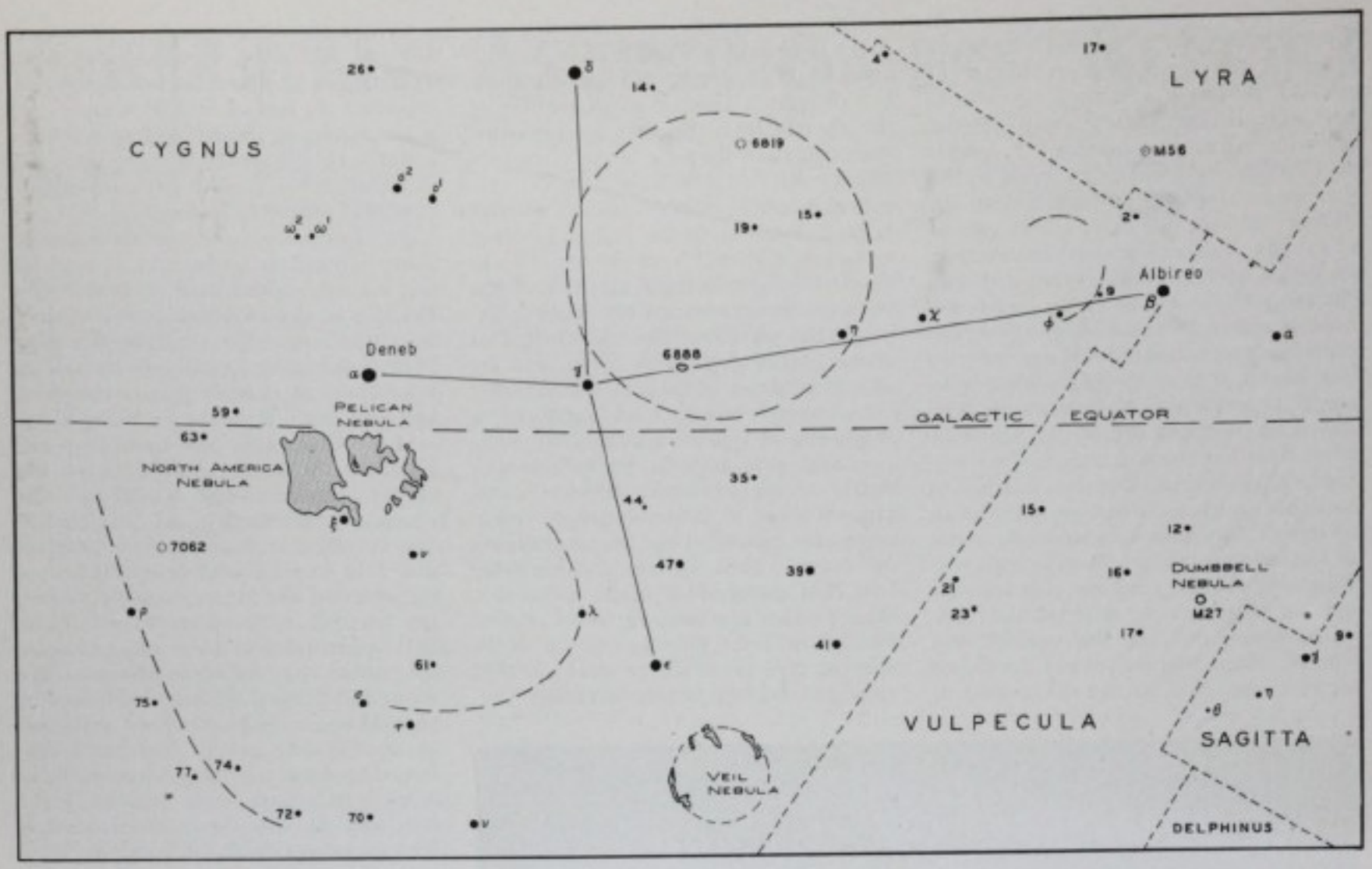
The plateholder of the 48-inch telescope is oriented with its edges extending north-south and east-west. However, in the Cygnus region, the Milky Way runs at a very considerable angle to the celestial equator. Hence, as seen in the reproductions of the mosaic here and on the center pages, the prints had to be arranged obliquely to the central line of the mosaic—the galactic equator.

The mosaic covers most of the constellation of Cygnus, and sizable parts of Lyra, Vulpecula, and Sagitta. The familiar naked-eye star patterns are heavily masked by the chaotic nebulosities that dominate the picture. But we can trace out the bright stars of the Northern Cross: Alpha (Deneb), of magnitude 1.3, spectrum *A2*; Gamma (Sadr), 2.3, *F8*; Beta (Albireo), 3.2, *K0*; Delta, 3.0, *A0*; and Epsilon (Gienah), 2.6, *K0*. The orange stars Beta and Epsilon appear stronger than they do on the more common blue-sensitive plates. Gamma is so deeply immersed in nebulosity that its image is almost lost.

In describing this mosaic, Dr. Greenstein has said, "Any attempt to catalogue individual nebulosities is really intrinsically doomed to failure, because the famous bright regions are very often only the cores of larger extended ones. For example, the separation of the North America and the Pelican nebulae is clearly seen here to be due to a very light lane of interstellar absorption."

The region of the mosaic is the richest in gaseous clouds of any part of the northern Milky Way. The reason is easily understood from the drawing on page 120, which represents the distribution of neutral hydrogen gas as mapped by the Leiden radio astronomers. Their work is being published in the *Bulletin* of the Astronomical Institutes of the Netherlands (No. 473). It is evident that gaseous formations are characteristic of the spiral arms of the galaxy. The center of the Cygnus field is in galactic longitude about 45°, so we are observing nearly lengthwise through the outer spiral arms. No wonder that this part of the sky appears so rich in nebulosity.

The most interesting of these formations are the "enormous hollow bubbles of gas," to use Dr. Greenstein's expression. Several of these are indicated in the key to the photograph. The most famous is the Veil nebula, forming the filamentary wreaths near the lower edge of the field. Even larger bubbles are



A key chart for the mosaic on the facing page and in the center of this issue. The Northern Cross is outlined, and some of the large hydrogen spheres discussed in this article are indicated by dashed curves or circles.

seen near the central line of the Milky Way, and portions of several others appear as wispy arcs, where they are not obscured by dark clouds or overwhelmed by other bright nebulae.

Largest of these rings is the one appearing in part along the left edge of the mosaic—it would surround practically the entire constellation if it could be traced all along its circumference. Vast bubbles like this one are new discoveries; because of their large size they could not be recognized on single photographs.

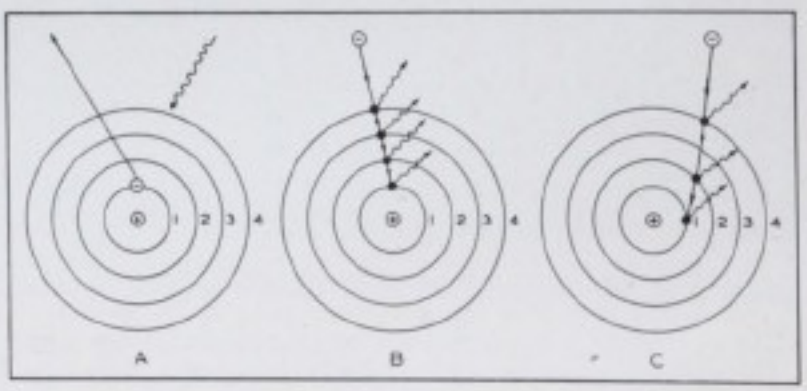
We identify these luminous rings with the ionized hydrogen (H-II) spheres, whose existence was predicted by B. Strömgren in 1938 from purely theoretical considerations. He studied the effect of ultraviolet light from hot stars in ionizing the hydrogen atoms in surrounding nebulosities. It is worth our considering briefly the processes involved.

The diagram illustrates the energy levels of a hydrogen atom on the elementary Bohr model, showing one process of ionization (loss of the electron) and two processes of recapture. The ionization occurs when the atom absorbs a quantum of ultraviolet starlight of wave length shorter than 911 angstroms (the Lyman limit). The negative electron escapes entirely from the control of the atom, which is therefore ionized and possesses a positive electrical charge that attracts other negative electrons.

The free electrons in a body of gas that has been ionized in this manner encounter the hydrogen ions (protons) and are captured by a process called recombination. Among all the possible energy levels to which an electron can return, we are interested in those involving a drop of the electron from the third to the second level, for then the atom emits radiation at the wave length of the hydrogen-alpha line in the Balmer series. It is this wave length at which our red-sensitive plates record the hydrogen nebulosities. The process involved is shown in part B of the diagram.

The brightness of a nebula is therefore proportional to the number of protons in the gas; if there were no protons there could be no captures and the brightness would be zero. The brightness similarly is proportional to the number of free electrons. But a gaseous nebula consists almost entirely of hydrogen, and nearly all of the free electrons have resulted from the ionization of hydrogen atoms—the other chemical elements present play only an insignificant role. Each time a hydrogen atom is ionized, one proton and one electron are produced—thus the numbers of protons and electrons are practically equal, and the brightness of the nebula is proportional to the product of these equal numbers, or to the square of the number of atoms that are ionized.

It is thus necessary, to predict the brightness of the nebula, to know the proportion of the atoms that have been ionized. As already mentioned, the ionization of interstellar gas is caused by quanta of ultraviolet light furnished by the radiation of very hot stars, chiefly those with surface temperatures of 20,000° absolute or more. The brightnesses of our bubbles of gas do not change appreciably over intervals of many years, and hence their ionization and recombination processes must be in



Schematic views of a Bohr hydrogen atom, illustrating ionization (left) and electron capture. In B, a free electron is first caught in orbit 4, and cascades to orbits 3, 2, and 1 in turn, releasing a quantum of Paschen-alpha, Balmer-alpha, and Lyman-alpha radiation, respectively.

equilibrium. That is, the number of quanta disrupting neutral hydrogen atoms is the same as the number of protons capturing electrons to reconstitute neutral atoms of the same element.

Furthermore, the number of quanta that succeed in disrupting neutral hydrogen atoms must be proportional to the number of such atoms per unit volume of the gas. From these considerations, we find that, in a given volume of gas, *the ratio of the square of the number of ionized atoms to the number of neutral atoms is proportional to the number of available quanta of the appropriate wave length to accomplish the ionization.* This statement is essentially M. N. Saha's famous equation of ionization.

We have next to find the number of available quanta. If the gas with which we are dealing were located inside a star of known temperature, Planck's quantum theory would be used to calculate the number of quanta per unit volume (radiation density) that have the required wave lengths. Saha's equation was developed for this case only, but we can extend its results to a nebula far from the star.

We must take into account the attenuation of the light with distance—the number of quanta falls off as the square of the distance from the star. Furthermore, the nebula absorbs some of the ultraviolet stellar radiation. Strömgren's great contribution to the study of gaseous nebulae is his evaluation of the factors involved at various distances from the star. Up to a certain distance from the star, almost all the hydrogen atoms are ionized; beyond this distance the proportion of atoms ionized rapidly decreases, and for all practical purposes becomes zero.

Strömgren's computations show that a single star of type *O*, whose surface temperature is as high as 60,000°, ionizes nearly all the hydrogen atoms to a distance of about 50 parsecs (160 light-years); at greater distances there is practically no ionization. Thus, the star is surrounded by a H-II sphere of 50 parsecs radius, outside of which is a large region of neutral hydrogen, H I. A cluster of 10 or 15 stars of type *O* would produce an H-II sphere about 300 parsecs in radius.

Dutch radio observations of 21-cm. emission from neutral hydrogen clouds in the Milky Way give this picture of part of our galaxy. The center of the system is marked by a cross, the sun by a small dot, from which diverging lines bound the region of the 48-inch Schmidt mosaic. Courtesy Leiden Observatory.

Cooler stars have smaller spheres. A *B0* star, at 25,000°, is surrounded by an H-II region 12 parsecs in radius; a main-sequence *A0* star of 10,000° temperature gives rise to an ionized hydrogen sphere scarcely $1\frac{1}{4}$ light-years in diameter. The sun itself is too cool to have any significant H-II sphere of its own.

An observational check of these predictions is possible, as the sizes of some of the ionized regions may be found with the help of the known distances of their associated stars. For example, the large H-II region near Lambda Orionis is almost five degrees or 40 parsecs in radius, agreeing with Strömgren's calculations.

Many interesting questions are suggested by this theory, of which only a few can be mentioned here. Could our solar system be embedded in an H-II region? The nearest *O* stars are Gamma Velorum and Zeta Puppis, with temperatures of the order of 35,000° or 40,000°, as they are both of rather late *O*-type. Their H-II spheres would have radii of some 30 parsecs, but as their distances are about 200 parsecs, we are clearly not in an H-II region. This has been confirmed by observations at the McDonald Observatory of the night-sky spectrum; there is no hydrogen glow all over the night sky, only in sharply bounded though often large regions along the Milky Way.

Another problem involves the appearance of the ionization spheres. Within an H-II region the hydrogen is almost completely ionized. Therefore, the hydrogen emission should be almost constant per unit volume of the sphere. But our line of sight passes through a greater length of ionized gas near the center of the nebular disk than near the edges. From this effect we should expect the surface brightness of an H-II region to be greater toward its center. In reality, most H-II regions look like bubbles of gas, as though the light came from a thin outer shell, rather than from the entire volume. It would seem that the ultraviolet radiation from the central star or stars is not the only cause of emission by the outer shell.

Perhaps the explanation is that all ionized hydrogen shells expand. The expansion of the Veil nebula has been measured by E. P. Hubble and J. C. Duncan. It amounts to 0.05 second of arc per year, as though the nebulous material had been expelled from a supernova explosion about 150,000 years ago. Such expanding H-II regions must collide with relatively stationary interstellar clouds, and this should cause collisional excitation of the hydrogen. This process has been studied theoretically by J. H. Oort and others.

Collisions with other clouds may also account for the filamentary structure nearly always shown by the gaseous bubbles. Some ionized hydrogen regions are not exactly circular in cross section; they may have become deformed in one-sided collisions.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the joint meeting of the American Astronomical Society and the Astronomical Society of the Pacific at Berkeley, California, in August. Complete abstracts will appear in the Astronomical Journal *and the* Publications *of the Astronomical Society of the Pacific.*

Evolution in the Galaxy

Under the chairmanship of Jesse L. Greenstein, Mount Wilson and Palomar Observatories, a symposium was held on evolution in the galaxy. It was followed by a panel discussion featuring the symposium members, who were A. Blaauw, Yerkes Observatory; A. R. Sandage, Mount Wilson and Palomar Observatories; L. G. Henyey, Leuschner Observatory; and W. A. Fowler, California Institute of Technology.

Dr. Blaauw's title was "Kinematics, Duplicity, Luminosities, and Ages of Early-type Stars." He dealt mainly with the properties of stars of spectral types *O* to *B*3 lying on and above the main sequence of the spectrum-luminosity diagram. Only a fraction of the present stellar population has originated from these massive stars, but they are the most accessible ones for detailed study and are also those in which the most rapid evolutionary changes take place.

The Yerkes astronomer pointed out that in many star associations there are different ages—from one to 10 million years—for different parts of the same association. In the Orion association the densest part has stars of earliest spectral type, associated with nebulosity. He concludes that the loose, outer regions are the oldest parts of the association.

Dr. Blaauw discussed the relation of high-velocity stars and associations. A surprisingly large number of high-velocity *O* and early *B* stars are produced in associations; some of these are of such high velocity that they may even escape from the galaxy's gravitational field.

The early-type stars contain a high percentage of double or multiple stars. An outstanding phenomenon is the relation between the space velocity and the occurrence of such systems. Young stars with high initial velocities are seldom double, whereas those for which such velocities are small are quite often double. This distinction may have an important bearing on the process of star formation. Dr. Blaauw suggested that in studies of stellar populations more attention be paid to the properties of double stars.

Referring to the Hertzsprung-Russell diagram of spectral types and luminosities for galactic clusters of all ages (*Sky and Telescope*, February, 1956, page 167), Dr. Sandage asked questions that must be answered by theories on the evolution of stars. Why does the shape of the evolutionary track of an individual star depend on its mass? Why are the tracks nearly horizontal for stars more massive than those in the Beehive cluster while they slope upward into the giant region for stars of mass 2.5 and smaller?

Why is the Hertzsprung gap wedge-shaped? This gap separates main-sequence stars from giants in the upper middle part of the diagram, but it is believed that stars evolve across the gap from the main sequence to the giant branch. There is no gap for M67, while it is 1.6 magnitudes wide in color index for h and Chi Persei (the Double Cluster). For stars at the base of the wedge, the nitrogen-carbon cycle seems to be just dominant over the proton-proton reaction as a source of energy. The possible existence of a convective core may affect the structure of a star in this critical region of the diagram.

In the discussion of Dr. Sandage's work, W. P. Bidelman, Lick Observatory, pointed out that the Beehive has one star in the middle of the gap—a *G*-type giant. He said that this and other similar *G* stars are often peculiar, with very broad spectral lines. Dr. Henyey suggested that the formation of the very expanded outer envelope typical of a giant star is what stops the rapid expansion and evolution of a main-sequence star at the giant stage.

Concerning his own paper, "A Summary of Calculations on Stellar Evolution," Dr. Henyey emphasized that his stars exist only in the mechanism of the high-speed electronic Univac calculator of the Atomic Energy Commission facility at Livermore, California. He described computations dealing with hotter stars in which the outer convective regions are relatively unimportant. The masses involved range from 1.5 to 20 times the sun's, and the time-scale for the depletion of the hypothetical stars' hydrogen was determined. The rate of hydrogen consumption increases with the temperature, although this is a leisurely phase in a star's history.

It is the period during which a star slowly changes its position within the confines of the main sequence. Stars of spectral type *O*8, with 20 solar masses, evolve the most rapidly; from their original formation they contract in a very short time to the main-sequence position. There they spend a few million years and are relatively stable before the loss of their hydrogen makes them move to the right toward the giant branch. They end the hydrogen-depletion stage just when the more slowly evolving stars of mass 6 (type *B*5) are beginning it. But in contrast to these rapidly evolving stars, those of the sun's type and mass spend at least a billion (10^9) years on the main sequence.

Dr. Fowler's talk dealt with several problems of nuclear energy production and element formation in stars, a subject of great complexity and rapid change that was discussed by Otto Struve recently (*Sky and Telescope*, July and August, 1956). During his work at the Kellogg Radiation Laboratory, Dr. Fowler has calculated a possible time-scale for element synthesis in the galaxy before the formation of the solar system.

Two isotopes of uranium are compared, those of atomic weights 235 and 238; they now have an abundance ratio of

Astronomers on the panel of the symposium on evolution in the galaxy: (left to right) Drs. Greenstein, Blaauw, Sandage, Henyey, and Fowler.

1 to 139, whereas the element-building process of neutron capture indicates that originally there was as much or more U^{235} than U^{238}. The former isotope decays radioactively at a much faster rate than the latter; from the known rates of decay it is possible to compute the time elapsed since the original abundances were nearly equal. On this basis, the age of the galaxy is of the order of 7.5×10^9 years or more.

Theories of stellar evolution must take into account the existence and peculiarities of white dwarf stars, which were the subject of Dr. Greenstein's paper in the symposium. He emphasized the need for more observations of the distances and motions of white dwarfs and other very faint stars. For instance, a scant 19 binary systems are known to contain white dwarfs, yet only from such cases can we obtain direct information about the masses of these stars. The companion of Sirius is one of the few examples of a white dwarf of known mass.

Dr. Greenstein has studied 40 white dwarfs with the 200-inch telescope, and with it he expects to get spectra for all such objects to a magnitude limit of 16.5 at a dispersion of 180 angstroms per millimeter. He has been aided by observing lists and charts from W. J. Luyten, University of Minnesota Observatory. Dr. Greenstein cautioned that studies of these stars based on their colors require considerable care—the faintest white dwarf is actually almost as red as a typical *M*-type star!

The hottest white dwarfs appear to have surface temperatures of only about 25,000° absolute, instead of 100,000°. Their masses average half that of the sun, ranging from about 0.2 to 0.8, except for the companion of Sirius, which is greater. The central density of a typical white dwarf is about 2×10^6 grams per cubic centimeter, or about 30 tons each cubic inch. Extreme white dwarfs contain the densest matter known anywhere in the universe.

All white dwarfs have lost an enormous amount of their original mass—more than two thirds if they are of Population II, about 90 per cent if of Population I. As these stars appear now to be dominantly helium and heavy elements, a large fraction of the stellar mass that has evolved in either population has been returned to the interstellar medium, presumably with an enrichment of its heavy-element content. Dr. Greenstein said this was a "wonderful way of feeding matter back to the interstellar medium."

The white dwarf stage for a star is one of very slow cooling, requiring billions of years. The great ages of some white dwarfs indicate that there has been a long interval between the formation of the Milky Way galaxy and the birth of our sun. This, in turn, implies the existence of large numbers of extremely faint, red degenerate stars.

Radio Observations of Venus

Two types of 11-meter radio static from the planet Venus can now be distinguished, according to John D. Kraus, Ohio State University, who has extended the observations reported in the August, 1956, *Sky and Telescope* (pages 435 and 444). First, there are very short bursts lasting only a small fraction of a second, which may originate in electrical discharges on Venus similar to terrestrial lightning strokes. The second type consists of sustained pulses often lasting a second or more, building up gradually and ending abruptly.

Considerable fluctuation in intensity of the very short bursts occurs, with a tendency for active periods to recur at 13-day intervals. On the assumption that such signals originate at one or a few localized regions on Venus' surface, Dr. Kraus interpreted this periodicity as a stroboscopic effect imposed by the rotations of the earth and Venus; he suggested that the length of a day on Venus may be about 22 hours 17 minutes.

The sustained pulses show a modulation at about 125 cycles per second, and occur over a band-width of two or more megacycles. Ordinarily, such pulses are randomly spaced, but occasionally their separations are quite uniform, as on the occasion when 25 successive pulses were observed at regular 6¼-second intervals.

Solar Corona Observations

The sun's corona as observed during an eclipse has two white-light components: the F-corona, generally considered to be caused by sunlight scattered by particles similar in nature to those that cause the zodiacal light (*Sky and Telescope*, March, 1954, page 144); and the K-corona, which is part of the sun's outer atmosphere, having a continuous spectrum and often called the electron corona.

At the High Altitude Observatory a coronagraph has been supplemented with sensitive photoelectric equipment that can detect the K-corona, without requiring an eclipse, at distances from the edge of the sun of half its radius and more. The new instrument, called a K-coronameter, was developed by G. Wlérick, J. Axtell, and R. Lee.

The detection of the corona in this manner is based on the fact that its light is polarized. The analyzer of polarization consists essentially of an electrically birefringent crystal excited by an alternating-current voltage, a polarizer, and a Lallemand photomultiplier. The a.c. signal from the multiplier is fed to a narrow-band amplifier with synchronous detection. The band-width is of the order of a few cycles per second.

To reduce as much as possible any polarization introduced by the instrument itself, the coronal observations are always made on the optical axis. Thus, when scanning around the sun's limb, the axis of the instrument describes a cone. A complete scan, at one given distance from the limb, takes four minutes. During the scan, a rotating half-wave plate keeps the plane of polarization fixed in direction with respect to the analyzer.

Even at the relatively low altitude of Boulder, Colorado, where the High Altitude Observatory headquarters are located, it has been possible to detect the main features or streamers of the corona up to about 200,000 miles and higher above the sun's surface. There is generally good correlation between the brightness of the electron corona measured with this instrument and the intensity of the green coronal emission line (produced by atoms of iron ionized 13 times) measured with a conventional coronagraph. The K-coronameter has now been moved to the Climax station, over 11,000 feet above sea level, where better sky conditions should give even greater effectiveness.

Temperature of the Corona

When the temperature of the solar corona is determined from the emission lines of its highly ionized atoms, two very widely differing results are obtained: about two million degrees, based on the thermal broadening of the lines, and about 700,000°, from the relative intensities of lines representing different degrees of ionization of the same element (such as iron).

D. E. Billings, High Altitude Observatory, has used a large number of spectra from the new Climax spectrograph, measuring the profiles of the red [Fe X] and green [Fe XIV] lines, to find a marked correlation between the two kinds of temperatures. He believes that this indicates the broadening of the coronal lines to be primarily thermal and that the temperatures must actually be in the two-million degree range. The atomic data on which the line-intensity method depends should be re-examined, and perhaps the discrepancy between the two kinds of temperature will be removed.

Gravitational and Atomic Time-Scales

A joint program is under way by the National Physical Laboratory, Teddington, England, and the U. S. Naval Observatory to decide whether time as defined by atomic processes flows at the same rate as time defined by motions of bodies in the solar system. The plan, as reported by W. Markowitz and R. G. Hall, U. S. Naval Observatory, is to determine the frequency of an atomic standard in terms of gravitational time in different years, and to see if this frequency is changing progressively.

At Teddington, a cesium-beam atomic clock was put into operation in 1955 by L. Essen and J. V. L. Parry. This standard can be compared with a precision quartz-crystal clock. At Washington, other quartz clocks are compared with the

rotation of the earth, as determined by star observations with the photographic zenith tube. Observations of the moon, with the dual-rate camera invented by Dr. Markowitz, allow elimination of the effects of nonuniformity in the earth's rotation.

The final link in the procedure is the intercomparison by radio of the quartz clocks in England and America. If it exists, a change of about one part in a billion per year in the gravitational and atomic time-scales relative to each other may be detected by about 1970.

Precise Orbits of Meteors

At the Smithsonian Astrophysical Observatory, F. L. Whipple and L. G. Jacchia have determined unusually accurate orbits of 308 meteors—a selection from the highest quality photographs taken with the Baker super-Schmidt meteor cameras in New Mexico. For these 308 objects, velocities within the earth's atmosphere could be measured with an accuracy of within about 0.3 per cent.

None of these meteors was found to have a definitely hyperbolic orbit around the sun. The Smithsonian astronomers conclude that meteors from interstellar space comprise less than one per cent of those observed visually, if indeed they exist at all.

Over 90 per cent of this sample of meteors had orbits indicating a cometary origin. Some 30 per cent of the orbits were of long periods and random orientations; almost all of the remainder had motions characteristic of short-period comets.

Mass of M81

High-dispersion spectrographic observations with the 200-inch telescope have enabled Guido Münch, Mount Wilson and Palomar Observatories, to make provisional estimates of the total mass of the Sb-type spiral galaxy Messier 81 in Ursa Major. He assumed that various parts of that galaxy revolve in circular orbits around its center of mass, the speeds of revolution being determined as if the mass of the galaxy as a whole were concentrated in its nucleus.

He measured the radial velocity of a patch of emission nebulosity lying about 43,000 light-years from the center of the system, on its major axis. Part of this radial velocity results from the motion toward us of M81 as a whole, at 45 kilometers per second. When this was allowed for, the emission nebulosity had a residual motion that Dr. Münch interpreted as due to orbital revolution around the center. From this he calculated the mass of M81 as 9.7×10^{10} solar masses.

A second determination was made in the same way, from hydrogen-emission regions in the bright arms of the system, about 16,000 light-years from the center. This gave a mass of 6.8×10^{10} suns.

The galaxy Messier 81 is seen as a well-formed spiral in this Mount Wilson Observatory photograph obtained with the 60-inch reflector.

In his work, Dr. Münch adopted A. R. Sandage's determination of the distance of M81 as seven million light-years (*Sky and Telescope*, April, 1954, page 188).

Convection Around Sunspots

Sunspots were described as "quiet islands" on the otherwise turbulent sun by D. H. Menzel, Harvard Observatory, who reported work by M. Krook, P. Wild, and himself, correlating solar radio noise bursts with activity on the sun.

Beneath the solar surface is a hot, unstable layer, from which blobs of heated gas rise by convection. Exploiting a suggestion by L. Biermann that the strong magnetic fields of sunspots hinder convection, the Harvard astronomers point out that the energy prevented from flowing up in a sunspot will leak out through the surrounding surface. As a result, the sun's photosphere adjoining sunspots is brighter than elsewhere because the increased convection brings hotter layers closer to the visible surface. Shock waves are formed and produce the radio noise bursts found by Dr. Wild to originate generally near sunspots.

On this model, prominence activity associated with sunspot groups should originate in the surrounding material rather than in the spots themselves. There should also be above-average heating of the chromosphere and corona near spots. This effect should appear, as in fact it does, before a spot has surfaced. Prominences visible as dark filaments on the disk (in hydrogen spectroheliograms) may similarly be associated with submerged magnetic fields.

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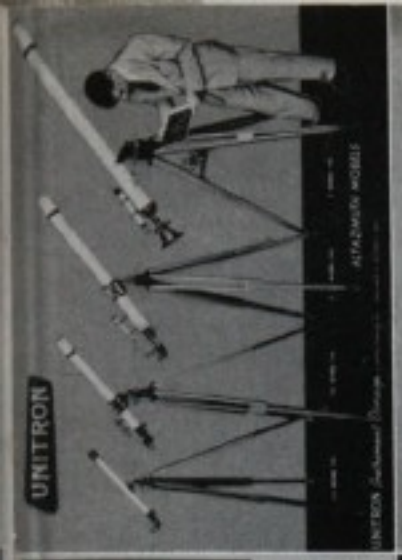

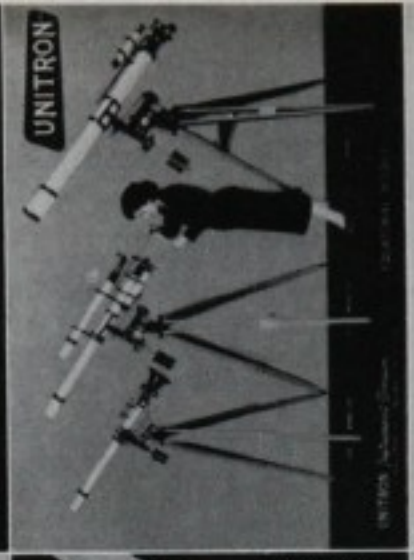

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BOOKS AND THE SKY

GASEOUS NEBULAE

L. H. Aller. John Wiley and Sons, Inc., New York, 1956. 322 pages. $11.00.

IN THIS BOOK, the first in English devoted wholly to this fascinating subject, an astronomer at the University of Michigan, L. H. Aller, has performed another of his noteworthy services to astrophysicists. Originally planned during the years 1940-1945, the work has been completely revised in the postwar years and now incorporates much new material obtained with the 200-inch and 100-inch telescopes, and some results from radio astronomy.

The first chapter describes the various types of nebulae known, and it is made clear that the planetaries will be emphasized more than any other objects. The diffuse galactic nebulae (to which the last chapter is devoted) form part of the interstellar medium, which is to be treated in a later book in the International Astrophysical Series. Another reason for specializing on the planetaries is that they are more truly gaseous. The diffuse galactic nebulae are usually composed of both dust and gas, hence showing complexities which are beautiful to the eye but bewildering to the theorist.

After an outline of the methods of observation, the results on distances, dimensions, and spectra are described. A theoretical treatment of physical processes in gaseous nebulae follows; the author has himself made many contributions to this work in the well-known Harvard series of papers. His clear treatment of the mathematics is to be commended; in particular, it is most helpful to have the astrophysical meaning of the separate terms printed alongside some of the more fundamental equations. Then there is a discussion of the forbidden lines in the spectra of planetaries, lines that have been used with such success by Bowen, Wyse, and others to derive ionic concentrations, and finally abundances of various atoms in planetary and diffuse nebulae.

Next, the central stars of the nebulae are considered. This chapter contains an interesting comparison of the temperatures of these stars derived by the methods of Zanstra, Stoy, and Ambarzumian. It is surprising that no mention is made here of the irregular variable AG Carinae, with a P-Cygni-type spectrum, which is surrounded by a large ring nebula. This object, several magnitudes brighter than the nucleus of any other planetary, may provide a clue to the evolution of such objects.

Chapter VII, on the structure and internal motions of the planetaries, will perhaps command the widest interest. Here are presented many hitherto unpublished observations from Mount Wilson and Palomar Observatories. Isophotic contours of various nebulae have been derived from 200-inch photographs by R. Minkowski, with plate-filter combinations that essentially isolate specific line radiations.

Similar results can also be derived from O. C. Wilson's beautiful spectra taken with the 100-inch slitless coude spectrograph. Such monochromatic images suffer from the disadvantage—compared with Minkowski's photographs—that the shapes are distorted by any Doppler motions that may be present. Doppler distortions in nebular lines were detected many years ago by W. W. Campbell and J. H. Moore (and erroneously attributed by them to rotation). The ingenious "multislit" of O. C. Wilson and G. Münch (*Sky and Telescope*, January, 1955, page 93) permits the study, simultaneously in a single long exposure, of the distortions shown by many different portions of the nebula.

Beautiful reproductions of the splitting of lines in NGC 7027 and NGC 7662 are given. These spectra assist the analyst to picture the nebula in three dimensions, whereas in studying an ordinary two-dimensional photograph one has to assume a certain degree of symmetry before space densities can be derived. Unfortunately, it is only in a few of the simplest nebulae that this assumption

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seems to be justified. The ideal nebula consists of a hot central star surrounded by a large uniform shell. It may be disquieting to some to read the author's confessions that "the complexities exhibited by most of the real nebulae are not amenable to theoretical discussion."

On page 17, the dimensions of a nebula are misprinted in units of *in.* instead of seconds of arc. On page 105, the possible identification of [Cr II] in HD 200775 ignores the fact that the spectrum of Eta Carinae makes it practically certain the line at 3993 angstroms is mainly due to [Ni II] and not [Cr II]; the relevant quotation should be corrected to *Publications* of the Astronomical Society of the Pacific, *61*, 265. But such blemishes are evidently rare in this book.

The reproductions are of very high quality, and in view of these and the wealth of up-to-date material the book's price can hardly be regarded as excessive. There can be no question of the immense value of this authoritative and critical volume to students and research workers.

A. D. THACKERAY
Radcliffe Observatory
Pretoria, South Africa

EARTH SATELLITES

Patrick Moore. W. W. Norton and Co., Inc., New York, 1956. 157 pages. $2.95.

A FAIR AMOUNT of one's reading time could be used just in keeping up with Patrick Moore. This prolific author has written many books in recent years, some of them with H. P. Wilkins, and he is now the editor of the new British Interplanetary Society magazine, *Spaceflight*. His latest volume attempts to render the subject of artificial satellites, and particularly Project Vanguard, intelligible to the layman who may have read only newspaper accounts. In this effort he is assisted by the illustrations of Irving Geis.

Mr. Moore covers the history of rockets and the development of high-altitude research vehicles and guided missiles. He discusses the uses of unmanned and manned satellites, for both research and military purposes. Stress is laid on upper-air research as a preliminary to thoughts of space travel, a point generally overlooked by enthusiastic writers. The book winds up with some "informed speculation about space travel."

There is a chapter on the moon, two pages of pictures of space people according to modern cartoonists, and on pages 104-105 a humorous drawing of a de luxe space station. This is a take-off on von Braun's revolving ring, complete with lobby, piano repair, Turkish bath, subway, burglar alarm, building and loan department, and many other installations.

A vast amount of information has been crammed into rather few pages, but on so many subjects that none is covered really well. There are numerous statements which, while technically accurate, may lead to false impressions. Oversimplifications abound, and may make many readers falsely believe they understand some technically formidable points.

This reviewer believes that serious readers interested in the history of rockets and space travel will find more meat in Willy Ley's *Rockets, Missiles, and Space Travel*, and that A. C. Clarke's *Interplanetary Flight* is probably a much safer guide to the plausible in space travel speculations. The new magazine, *Missiles and Rockets*, has already become notable for its up-to-date coverage of orbital vehicles. For engineers, there is the American Rocket Society's publication, *Jet Propulsion*, which, incidentally, carries information on Russian rocketry from time to time.

Specifically among the book's many weaknesses, which appear to result from hasty preparation, on pages 16 and 17

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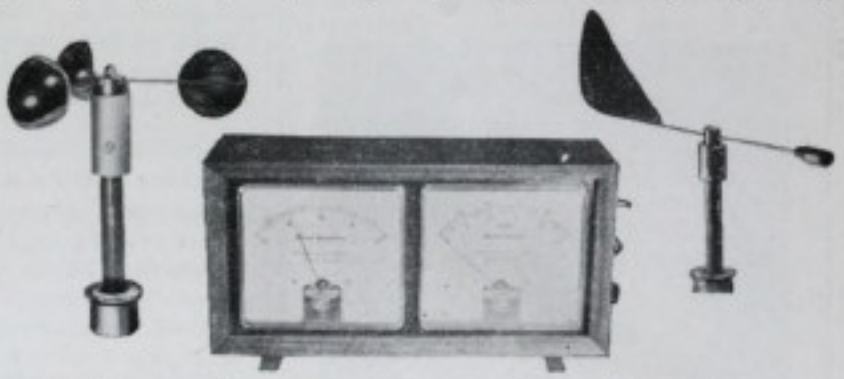

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THE MOON, by Wilkins and Moore...$12.00
GUIDE TO MARS, by P. Moore.....$ 2.50
THE MILKY WAY, by Bok and Bok..$ 5.50
Norton's STAR ATLAS.....$ 5.25
HANDBOOK of the British Astronomical Association for 1957.....$ 1.50

Books on telescope making, glass working.

All books and star atlases advertised and reviewed in Sky and Telescope. *Out-of-print books located.*

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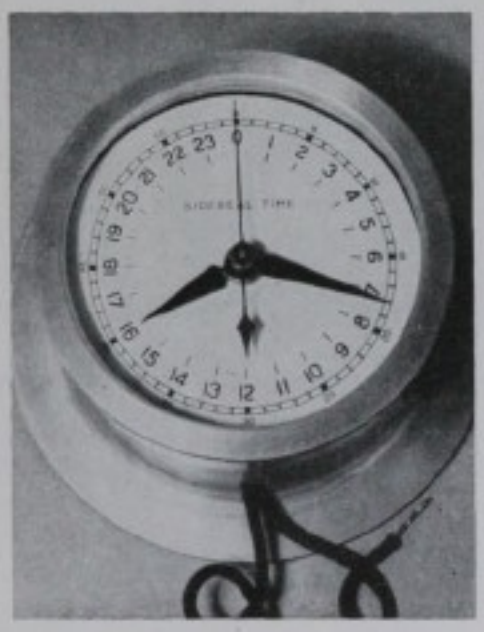

WHAT IS SIDEREAL TIME?

By definition it is the hour angle of the March equinox, which is at right ascension 0 hours. At your observing station the right ascension of the celestial meridian is always your local sidereal time.

Knowing the sidereal time is an astronomical necessity, for it tells you quickly the hour angle of any celestial body to which you wish to point your telescope.

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there is an explanation of orbital motion that would not satisfy a high-school student, and includes a reference to "solar flames." On pages 55 and 75 it is implied that the optimum moment for firing succeeding stages of multistage rockets is when the preceding stage has reached maximum altitude; actually, this moment is that of maximum velocity.

Mr. Moore indicates that tracking an artificial satellite will be no major problem—he has, after all, observed 10-mile Phobos with a 12½-inch reflector when Mars was 40 million miles away. But does this have anything to do with observing a body with an angular velocity of up to one degree per second? He also suggests casually that we will track the satellite by radar.

One wonders why the author labels "What lies on the far side of the Moon?" one of the burning questions of modern astronomy. Most astronomers merely assume that the far side of the moon is like the near one, and give the matter little further thought.

It is hard to recommend this book, for most of its intended readers will not have sufficient background to know when the author steps off base. Those sufficiently well informed will find the book just a delightful rehash of what they already know.

WILLIAM E. SHAWCROSS

NEW BOOKS RECEIVED

ASTRONOMICAL OPTICS AND RELATED SUBJECTS. *Zdenek Kopal*, editor, 1956, *Interscience*. $12.50. 428 pages.

The 46 sections of this book are the contributions presented at a symposium held in 1955 at the University of Manchester, England. They deal with topics under the following headings: information theory and optics, optical images and diffraction, interferometry and coherence problems, electronic devices in astronomical optics, resolution problems and scintillation, wide-angle optical systems and aspheric surfaces, filter photography and thin films.

A SPACE TRAVELER'S GUIDE TO MARS, *I. M. Levitt*, 1956, *Holt*. 175 pages. $3.50.

DR. LEVITT, who is director of the Fels Planetarium in Philadelphia, gives a straightforward account for popular readers of what is known about Mars. To this he adds sections on the origin of the solar system and on the possibilities of life on Mars and elsewhere in the universe.

ATOMS AND ENERGY, *H. S. W. Massey*, 1956, *Philosophical Library*. 174 pages. $4.75.

An offset reprint of a book first published several years ago, *Atoms and Energy* is a prominent British physicist's account for laymen of the atomic nucleus and the release and use of its energy.

GEOMETRICAL OPTICS, *L. C. Martin*, 1956, *Philosophical Library*. 215 pages. $7.50.

This textbook explains geometrical optics with emphasis on applications to optical instruments. There are also brief discussions of photometric principles, resolving power, and image aberrations.

APPARENT PLACES OF FUNDAMENTAL STARS 1957, 1956, *Her Majesty's Stationery Office*, York House, Kingsway, London W. C. 2. 536 pages. £2 2s.

Beginning with 1957, the *American Ephemeris* no longer contains apparent positions of bright stars, but these are available in this British publication, issued annually under the auspices of the International Astronomical Union. For 1,535 stars, right ascensions to 0.001 second and declinations to 0".01 are given at 10-day intervals. In the United States, this volume can be ordered for $7.82, postpaid, from the British Information Services, 30 Rockefeller Plaza, New York 20, N. Y.

THE OBSERVER'S HANDBOOK 1957, *C. A. Chant* and *Ruth Northcott*, editors, 1956, *Royal Astronomical Society of Canada*, 252 College St., Toronto 2B, Ontario. 84 pages. 75 cents, paper bound.

Now in its 49th year, this valuable aid to the amateur astronomer gives in easy-to-use form data for 1957 on the sun, moon, planets, Jupiter's satellites, and meteor showers. There are also variable star predictions, as well as listings of rising and setting times of the sun and moon especially adapted for observers in the United States and Canada. Other tables give facts on double stars, clusters, nebulae, and galaxies suitable for observing with amateur telescopes.

A particularly useful feature is a catalogue of the 286 stars brighter than magnitude 3.55, with colors, motions, distances, and absolute magnitudes. The magnitudes and colors cited depend on photoelectric measurements whenever possible, and thus are much more reliable than ordinary visual data.

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Graphic Time Table of the Heavens—1957

ON THE FOLLOWING pages is a chart that is a condensed and simple almanac, giving the rising and setting times of the sun, moon, and brighter planets, and much other useful astronomical information. This Graphic Time Table is published annually by the Maryland Academy of Sciences, through whose courtesy it is reproduced here for the 16th year. Separate copies may be obtained from the Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., for 25¢ each; discount on 20 or more. Large wall charts, 40 by 27 inches, $1.00.

How to Use the Graphic Time Table

Across the top of the chart are marked the hours from 4 p.m. to 8 a.m.; the days of the year run down the chart. Thus any event, like a particular sunset, can be indicated by a point on the chart. All such points are connected by a curve, and the time of sunset, for example, on any date in 1957 can be read from this curve, by following the horizontal line for the date to the sunset curve.

In this way the Graphic Time Table gives the rising and setting times of the sun and moon and the planets Mercury, Venus, Mars, Jupiter, and Saturn; the duration of twilight; and the times when certain stars and other interesting objects transit, that is, cross the meridian. The moon's phases are also indicated.

Small numbers at the left give the Julian day number. These numbers are a consecutive count of the days, beginning in 4713 B.C., so January 1, 1957, is JD 2,435,840. Julian days offer a simple way to find the interval between two dates by a single subtraction, and they are widely used by astronomers, particularly in variable star work. The Julian day number changes at Greenwich noon, or 6 a.m., Central standard time.

Along the midnight line are Roman numerals that indicate the sidereal time at midnight, in other words, the right ascension of a star then on the meridian at the date in question. Running along the midnight line and crossing it is the curve for the equation of time, which shows how much the sun is fast if the curve is to the left of the midnight line, and how much the sun is slow if the curve is to the right of the line. When the sun is fast, it arrives at the meridian before 12 o'clock noon, by the amount shown. In other words, this curve indicates the local mean solar time for the moment at which a properly adjusted sundial indicates noon.

Small black circles show moonset for the first half of each lunar month, and small open circles, moonrise from full to new moon. At longitude 75° west, the moon will rise about two minutes earlier than these times; at longitude 120° west, about four minutes later. Also plotted for the moon each day are little marks or "ticks," placed at the corresponding times for moonrise and moonset at the earth's equator; each tick has a horizontal bar pointing toward the time at 40° north, where the moon open or black circle is located. These marks aid interpolation for latitudes intermediate between the equator and 40° north, and may be used for cautious extrapolation to higher latitudes.

The scale at the right is for finding rising or setting times of other objects. Set dividers or a strip of paper from the index at the center of the scale to the object's declination, north or south (which must be known), and in the direction desired for either rising or setting. Measure this same distance along the midnight line of the chart beginning at the proper right ascension indicated by the Roman numerals. Should this end point fall outside the chart, add to or subtract from the right ascension 12 hours and reset the dividers, using the end of the scale rather than the center index. Through the point established, draw a line parallel to the vernal equinox line on the chart. This will show the time of the rising or setting of the object.

The Events of a Single Night

As an example, consider the night of January 3-4 by following the horizontal line for that date across the chart from left to right. The Julian day number is 2,435,842. Sunset occurs at 4:47 p.m., and at 5:07 the vernal equinox transits—marking 0^h local sidereal time. Mercury sets at 5:58 and Mars transits at 6:01, not long before twilight ends at 6:24. The upper culmination or transit of Polaris is at 6:59; moonset is at 7:40, followed by transits of the Pleiades at 8:51 and of the Orion nebula at 10:39. Jupiter rises at 11:12 and Sirius transits at 11:49. The sidereal time at midnight is 6:54; and a curve for the equation of time shows that the sun is slow, and will not reach the meridian until five minutes after 12 o'clock noon, local time, on January 4th. Mars sets at 12:21 a.m., Saturn rises at 4:49, and Jupiter transits at 5:13. Venus rises at 5:40, only five minutes before morning twilight begins. Polaris' lower transit is at 6:57, and sunrise is at 7:22 a.m.

How to Correct for Your Position

As in all almanacs, the times of rising and setting of the sun, moon, and planets are strictly correct for only one point on the earth's surface—for this chart, latitude 40° north and longitude 90° west. The observer may easily correct for his own position.

Correction for differences in longitude are chiefly to correct one's local time, shown by the Graphic Time Table, to the standard time of our clocks and watches. This correction depends solely on the distance of the observer east or west of his standard time meridian, the latter being an even multiple of 15 degrees: 75°, 90°, 105°, and 120° west longitude in the United States. In the following tabulation, in minutes of time, all places with plus corrections are west of the standard meridian:

Atlanta	+38	Memphis	0
Baltimore	+6	Milwaukee	−8
Birmingham	−13	Minneapolis	+13
Boston	−16	New Orleans	0
Buffalo	+15	New York	−4
Chicago	−10	Oklahoma City	+32
Cincinnati	+38	Philadelphia	+1
Cleveland	+27	Pittsburgh	+20
Denver	0	Rochester	+10
Detroit	+32	Salt Lake City	+28
Helena	+28	San Francisco	+10
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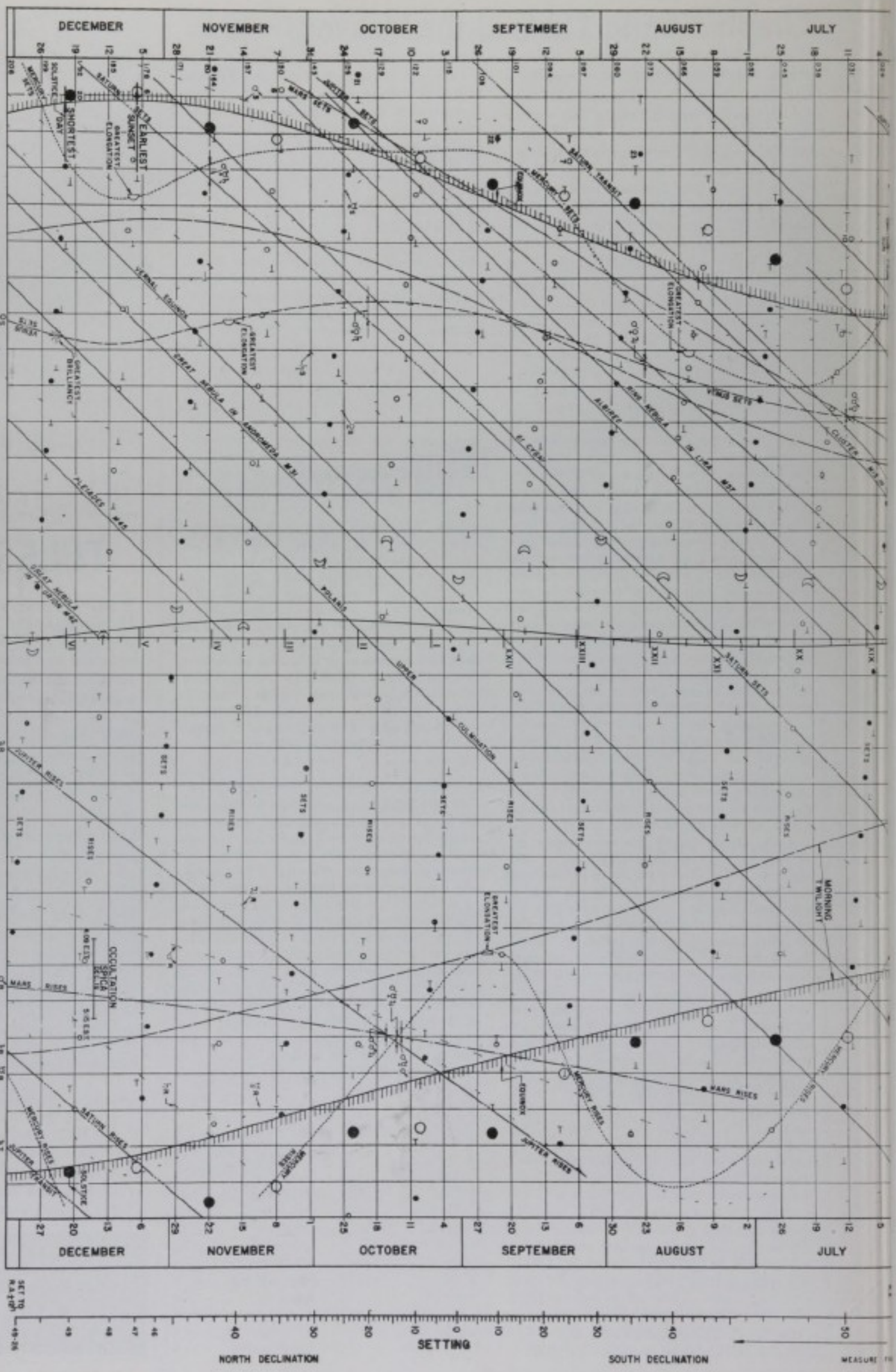
DECEMBER
NOVEMBER
OCTOBER
SEPTEMBER
AUGUST
JULY
STANDARD TIME
P. M.
MDT.
A. M.
SYMBOLS:
NEW MOON
FIRST QUARTER
FULL MOON
LAST QUARTER
GREATEST BRILLIANCY (VENUS)
CONJUNCTION
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
GREATEST ELONGATION
QUADRATURE
OPPOSITION
SHORTEST DAY
EARLIEST SUNSET
GREATEST BRILLIANCE
SOLSTICE
MERCURY RISES
MERCURY SETS
MARS SETS
JUPITER SETS
SATURN SETS
SATURN RISES
JUPITER RISES
MARS RISES
VENUS SETS
VENUS RISES
MORNING TWILIGHT
EVENING TWILIGHT
GREAT NEBULA IN ANDROMEDA, M31
GREAT NEBULA IN ORION, M42
PLEIADES, M45
BEEHIVE, M44
DOUBLE CLUSTER
ALGIEBA
GAMMA VIRGINIS
SET TO R.A. + (ϕ)
NORTH DECLINATION
SETTING
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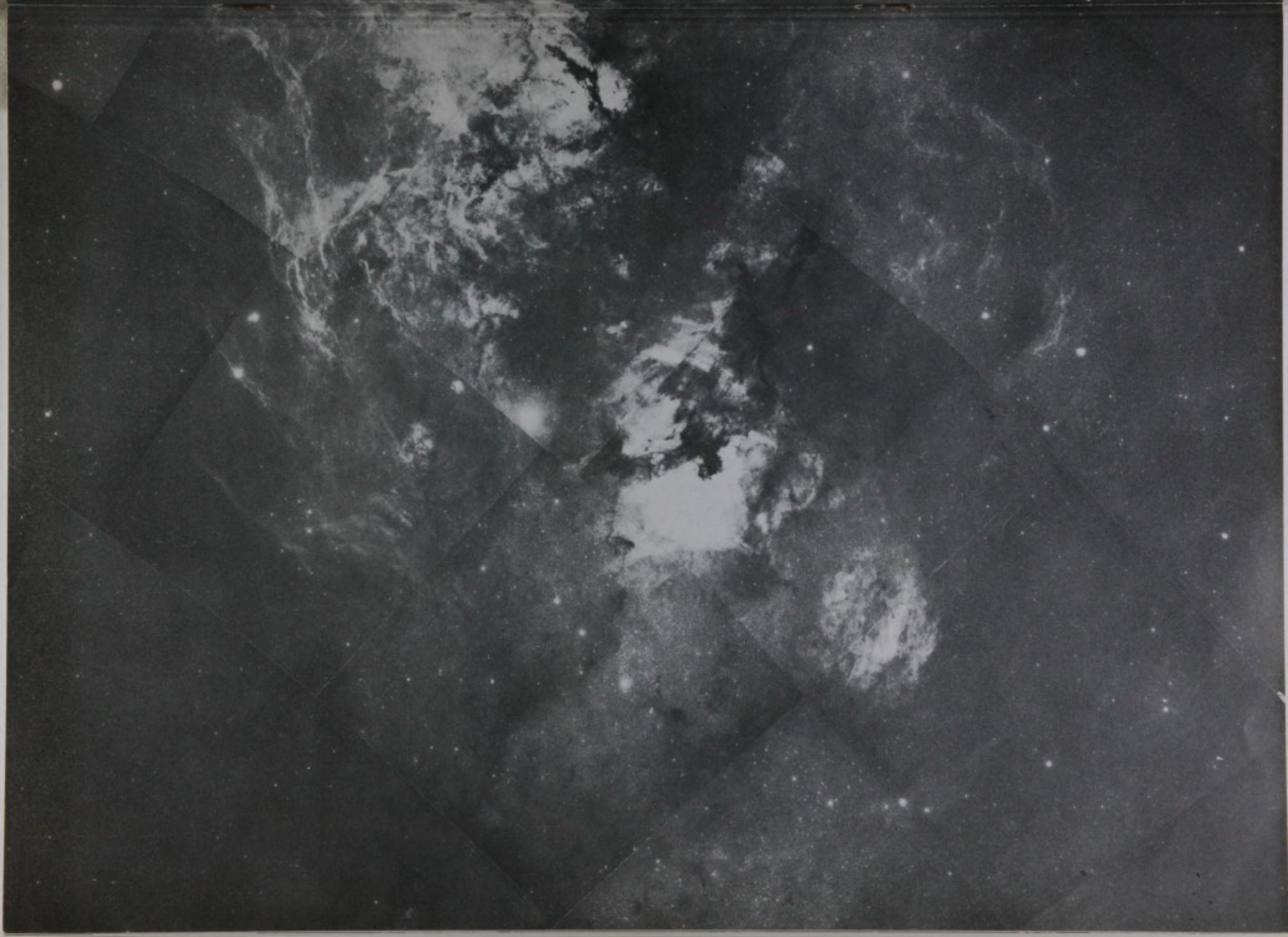

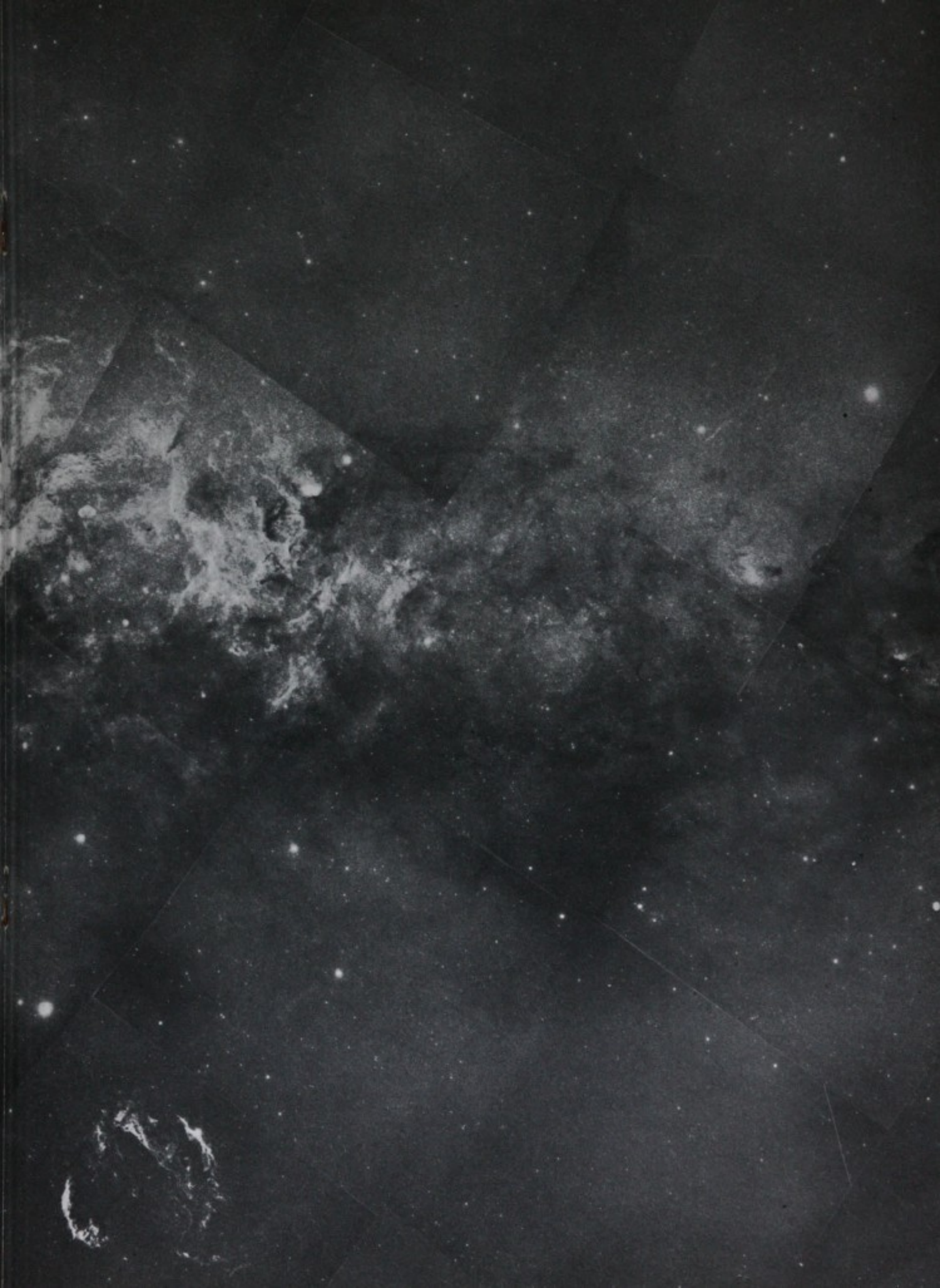

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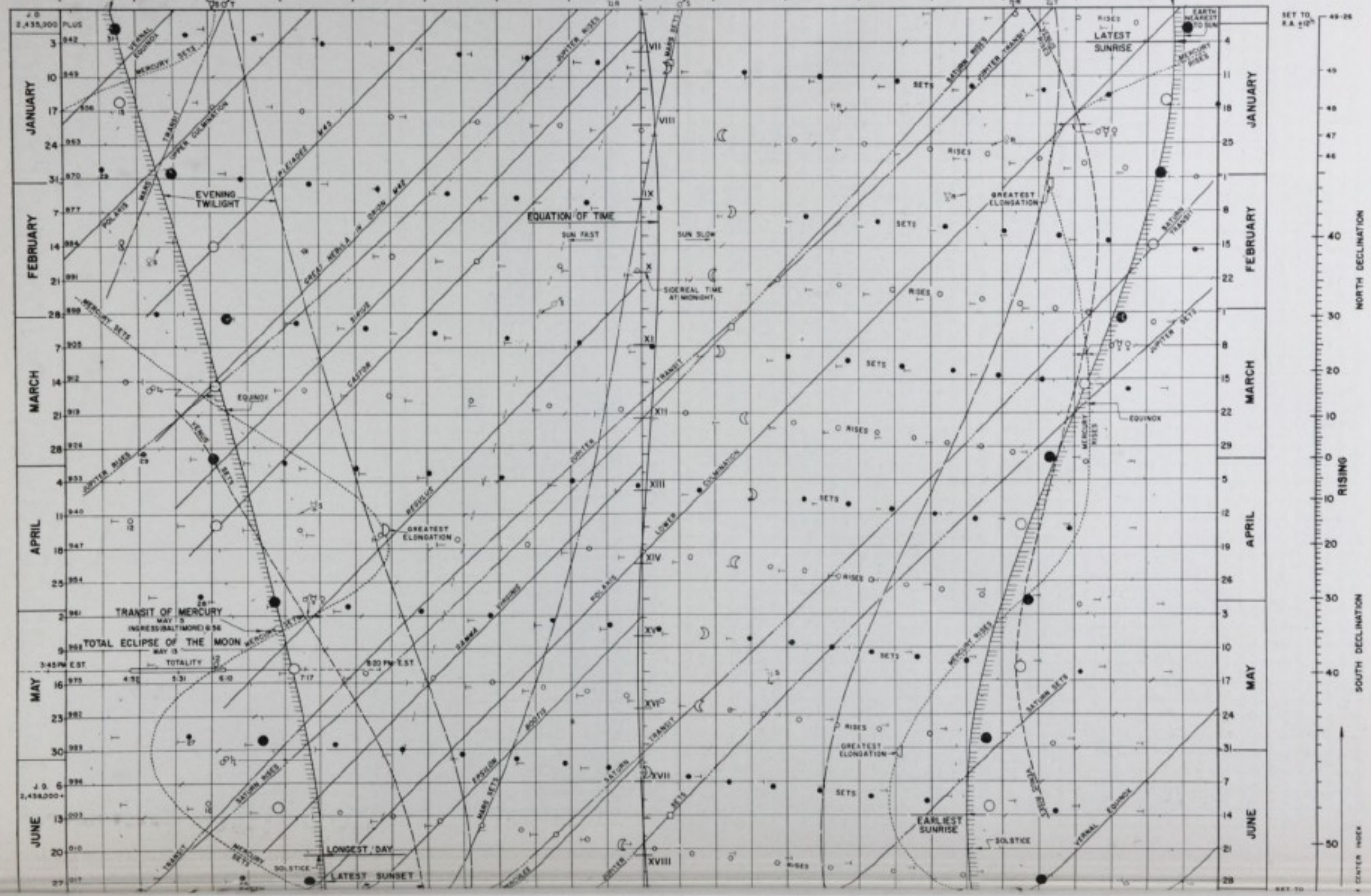
GRAPHIC TIME TABLE OF THE HEAVENS

YEAR 1957



A GUIDE TO ASTRONOMICAL EQUIPMENT

This listing provides an easy reference to manufacturers and suppliers of astronomical and allied equipment, who are advertising in this issue of Sky and Telescope. *Each check denotes a product the advertiser has in stock or will furnish to order. Some firms have other products besides these.*

Sky and TELESCOPE

PRODUCTS	ADVERTISERS: Ashbourne Bros.	Astro-Dome	Astronomy Charted	Bausch and Lomb	Brandon Instruments	Brayton Optical	Cave Optical	Leroy M. E. Clausing	Coast Instrument	A. Cottone	Criterion Manufacturing	Dome Building Systems	E. and W. Optical	Edmund Scientific	J. W. Fecker	Garth Optical	Frank Goodwin	Goto Optical	H. and W. Optical	Haines Scientific	International Screen	A. Jaegers	Laboratory Optical	Lafayette Radio	Herbert A. Luft	G. Magnusson	Nikon Optical	Nye Optical	Optron Laboratory	W. R. Parks	Precision Optical	Quality Optics	Questar	Harry Ross	Science Associates	Skyscope	Spitz Laboratories	Telescopics	Tinsley Laboratories	Unitron Instrument	David William Wolf	C. C. Young
INSTRUMENTS																																											
Binoculars	✓			✓				✓	✓	✓		✓	✓						✓		✓					✓	✓			✓	✓		✓									
Cameras (astronomical)	✓							✓					✓	✓						✓		✓				✓					✓								✓				
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Schmidt cameras							✓				✓		✓															✓													
TELESCOPE ACCESSORIES																																										
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Camera mountings							✓				✓		✓			✓										✓												✓				
Clock drives	✓					✓		✓					✓	✓		✓	✓	✓								✓										✓		✓				
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Multiple eyepiece holders	✓							✓					✓	✓												✓				✓			✓						✓			
Photometers													✓													✓															
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Sun projection screens	✓							✓					✓			✓										✓												✓			
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Mirror cells	✓					✓		✓		✓	✓	✓	✓													✓		✓	✓	✓		✓	✓			✓					✓
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Paraboloidal mirrors						✓	✓	✓		✓		✓	✓						✓								✓	✓		✓	✓		✓			✓	✓				
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Prism diagonals	✓				✓	✓		✓				✓	✓	✓					✓											✓	✓	✓	✓							
Secondary supports	✓					✓		✓		✓		✓	✓														✓			✓	✓					✓					
Slow-motion controls						✓		✓				✓	✓		✓		✓									✓															
Tripods						✓		✓	✓	✓		✓	✓																	✓	✓	✓	✓		✓					✓
Tubes	✓					✓		✓		✓	✓	✓	✓														✓		✓	✓	✓		✓	✓						
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Complete reflectors								✓		✓			✓		✓															✓	✓		✓			✓					
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Figuring						✓	✓	✓				✓			✓					✓						✓				✓	✓					✓					
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Books	✓		✓					✓		✓		✓	✓		✓				✓			✓								✓	✓		✓			✓					
Charts	✓		✓					✓		✓		✓	✓									✓								✓	✓					✓					
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Planispheres	✓																																		✓							
Sidereal clocks													✓					✓																							
Slides			✓																✓																						
Slide strips																			✓																						
Spitz Jr. planetariums	✓							✓		✓		✓																		✓				✓							
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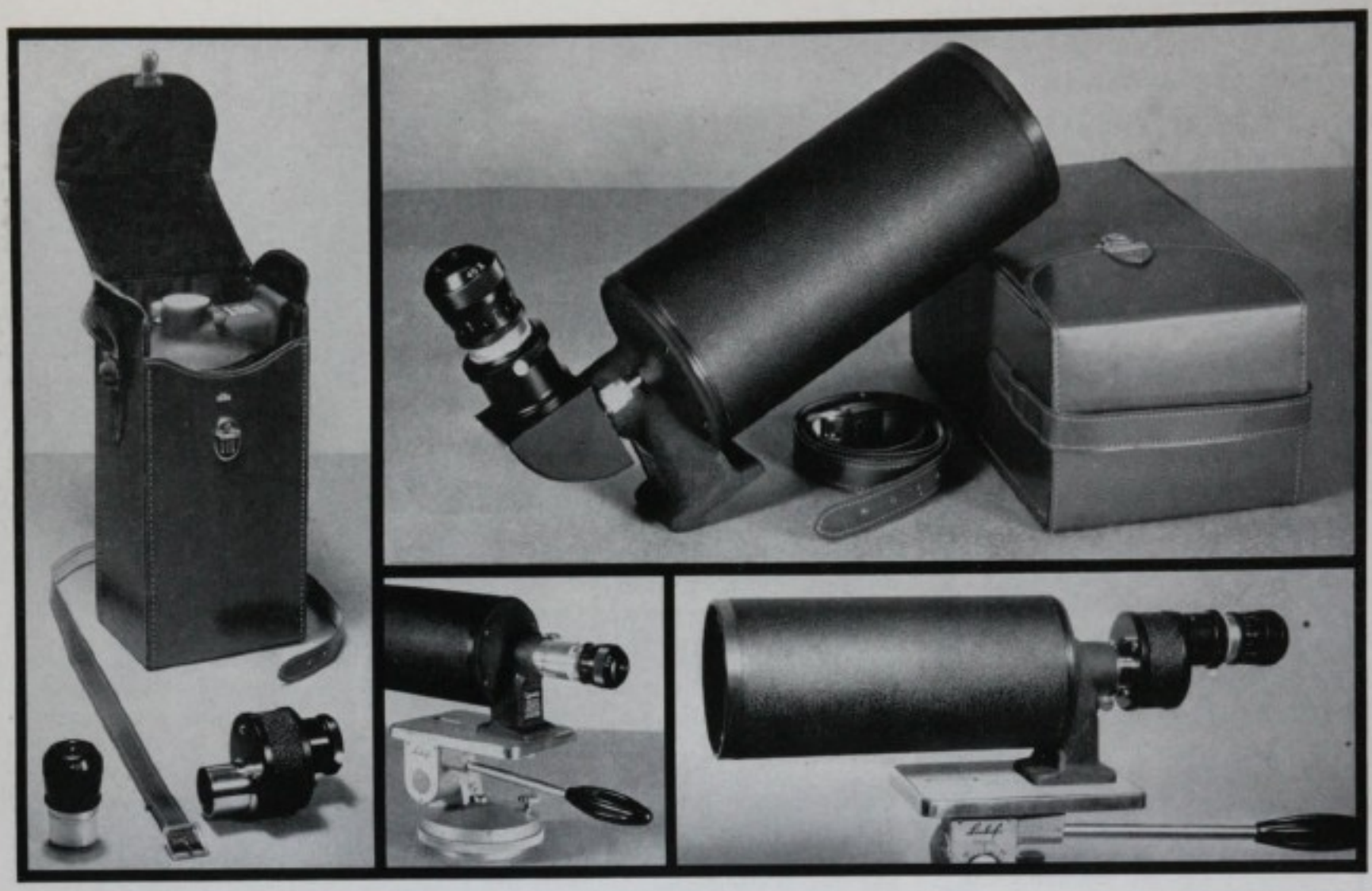

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Questar's aperture is 89 mm. (3.5 inches), its focal length, 1077 mm. (42.4 inches). Weight alone, 31 ounces; with case, 46 ounces. Focusing is internal, a small knob causing the mirror to move axially. We send each barrel to the Philadelphia studios of Albert Oldach and Son, fine bookbinders, where it is hand-covered in real Morocco.

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The famous Questar 80x 5-lens Erfle Eyepiece of 13-mm. f.l. and ultra-wide field of 75° is available separately at $25. This is the eyepiece that shows the moon so magnificently in its tremendous field.

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Both Star Diagonal and Prism Erecting System fit standard 1¼-inch tubes and eyepieces, and hold the latter without scratching by the adjustable friction of a nylon screw. Your choice of one is included with the Field Model and either may be purchased separately for $20.

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Questar's exclusive patented filter, the only sun-viewing device that keeps harmful solar heat where it belongs, wholly outside the telescope, is available separately at $25.

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The 1957 Field Model, complete with Case, Strap, 40x Eyepiece and Adapter Tube, and your choice of Star Diagonal or Prism Erecting System, is priced at only $495. On the Easy Payment Plan the down payment is $145, with 12 monthly payments of $30.92. Other accessories are sold separately, postpaid.

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The Custer 12½-inch Springfield Reflector — III

THE SPRINGFIELD telescope offers many advantages to the active amateur observer who wishes to enjoy maximum convenience with a large reflector. In the two previous installments we have described in detail the 12½-inch instrument of this type built and used by Dr. Clarence P. Custer, of Stockton, California. This month we continue with a look at the equatorial head and drive mechanism of this telescope.

Stability is a necessity with a Springfield mounting. Dr. Custer's telescope has been designed with sturdiness in mind, as can be seen in Fig. 14, a view from the west side of the mounting with the driving motors uncovered. In the lower left corner is the control box with four push buttons: the observer holds this in his hand and with it he can easily keep any object centered in the field of view.

Fig. 15 gives details of the differential motor drive, which contains two motors connected together as sketched in Fig. 16. The output shaft is floating, with its gear of 24 teeth meshing with the 15-tooth gear of the differential motor. Both 1,800 r.p.m. motors are of the reversible, synchronous type, geared down internally to 2 r.p.m. It is virtually impossible to turn the shaft of such a motor by outside force, due to the high internal gear ratio—a property made use of in this form of differential drive.

The shaft of the drive motor is securely fastened to the back plate of the differential motor mounting, and when the drive motor is running it turns the differential motor mount completely around twice a minute. Since the 15-tooth gear cannot be turned, it locks into the 24-tooth gear and drives the output shaft at 2 r.p.m. also. But when the differential motor is running in the same direction

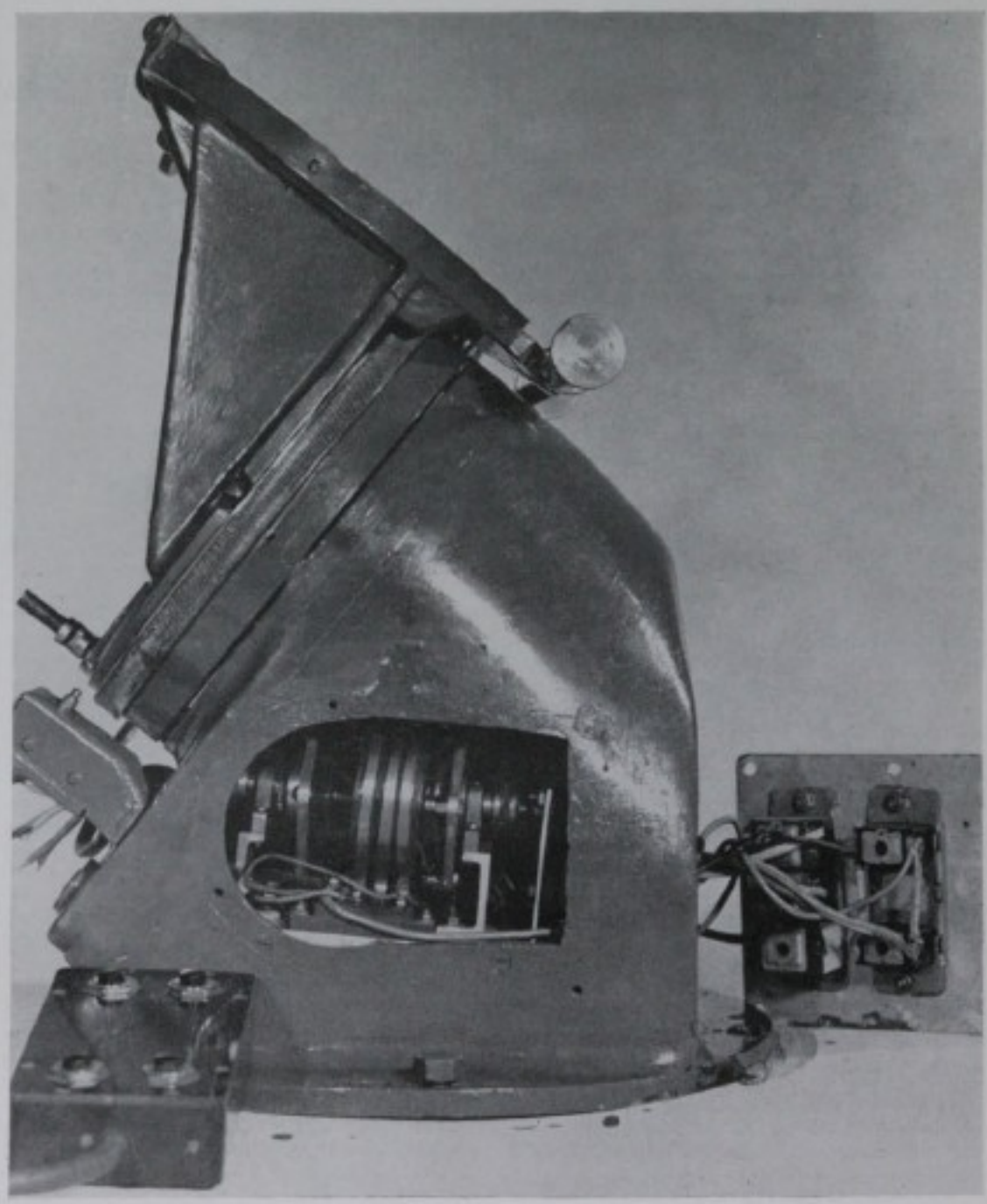

Fig. 14. The assembled equatorial head of the Custer telescope.

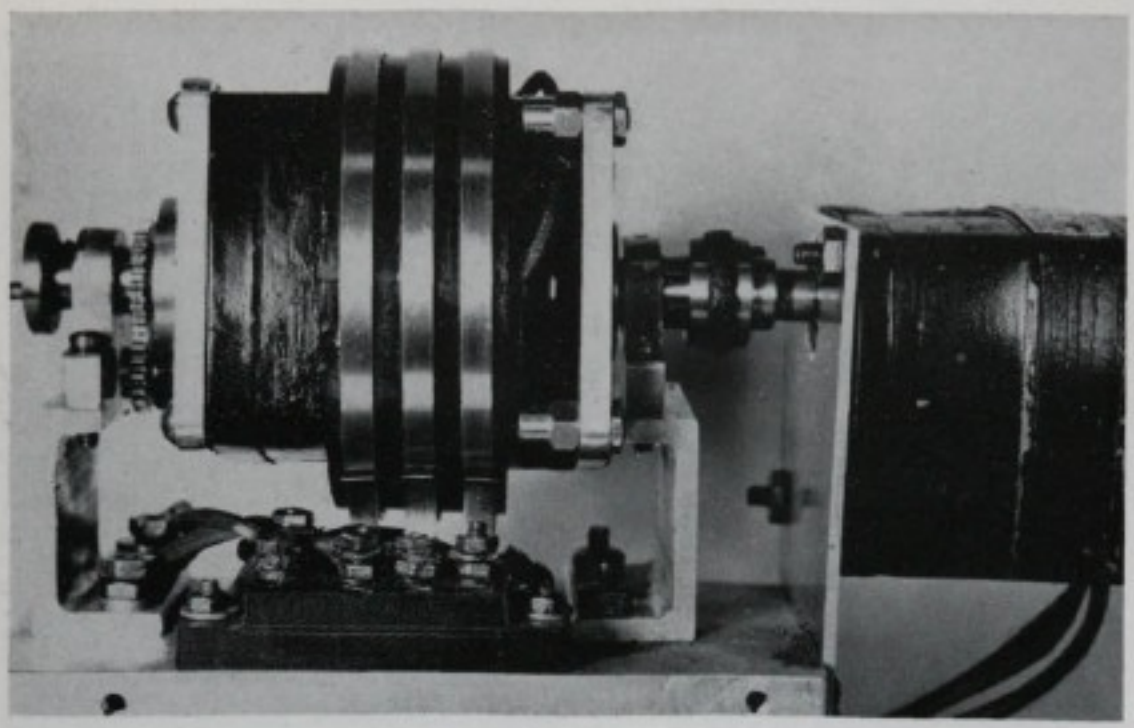

Fig. 15 (above). The motors of the differential drive.

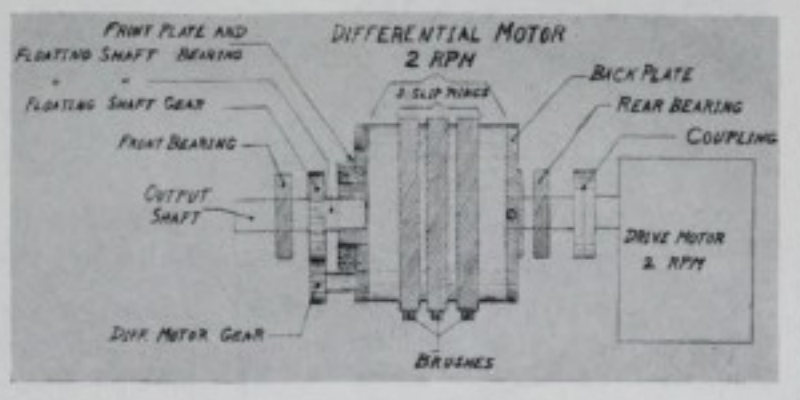

Fig. 16 (right). The tandem operation of the driving motors.

as the shaft of the drive motor, the action of its gear on the 24-tooth gear is to retard the rate of the output shaft. Instead of turning 10 times in five minutes, it now turns 3.75 times, or a decrease to about 3/8 normal speed. If the differential motor runs in the opposite direction to that of the driving motor, the output rate of the shaft is accelerated to 16.75 times in five minutes.

The interaction of these two motors may at first seem confusing, until it is realized that there is one gear connection between the differential motor and the output shaft that reverses the driving sense of that motor. If the drive motor were not running, then operation of the differential motor alone would turn the output shaft in the opposite direction to that of the differential motor.

These motors are each of 1/100 horsepower, but the differential motor might well have less power, to lessen any tendency to "coast" the guide star during photographic observations. There is a second leather coupling on the output shaft to isolate vibration, but this is not shown in Fig. 15.

The side view of Fig. 14 gives a good idea of the relation of the angle casting to the base casting, and shows the edges of the large worm gear and the ring casting between them. These latter two parts are lying bottom side up in Fig. 17, with parts of the clutch mechanism resting on the worm gear. The ring casting is bolted to the base by four countersunk Allen-head bolts, clearly seen in Fig. 18. The raised rim portion of this casting's upper face was machined to high accuracy, as it supports the whole weight of the telescope turning in right ascension. The worm gear rests on this rim, as indicated by the friction polish of its lower surface seen in Fig. 17.

On the left in Fig. 18 is the angle casting with the large opening of the declination axis toward the top. Below

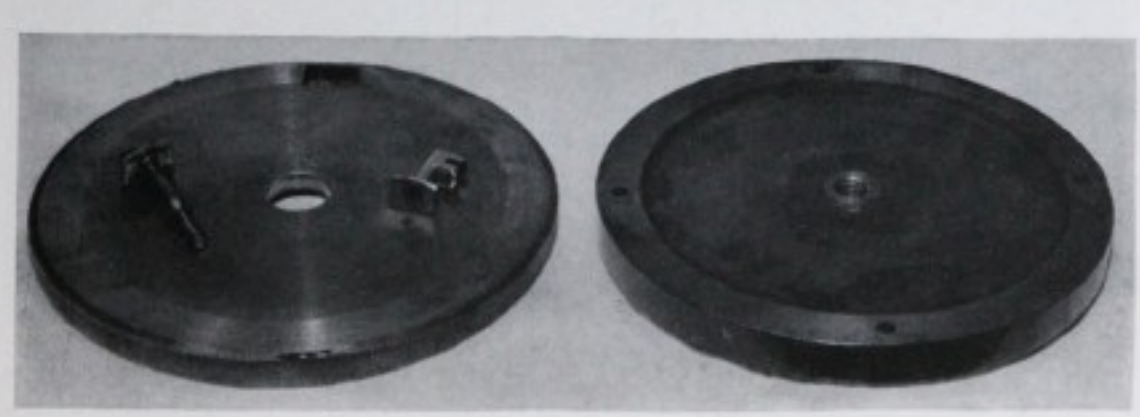

Fig. 17. The worm gear and the ring casting.

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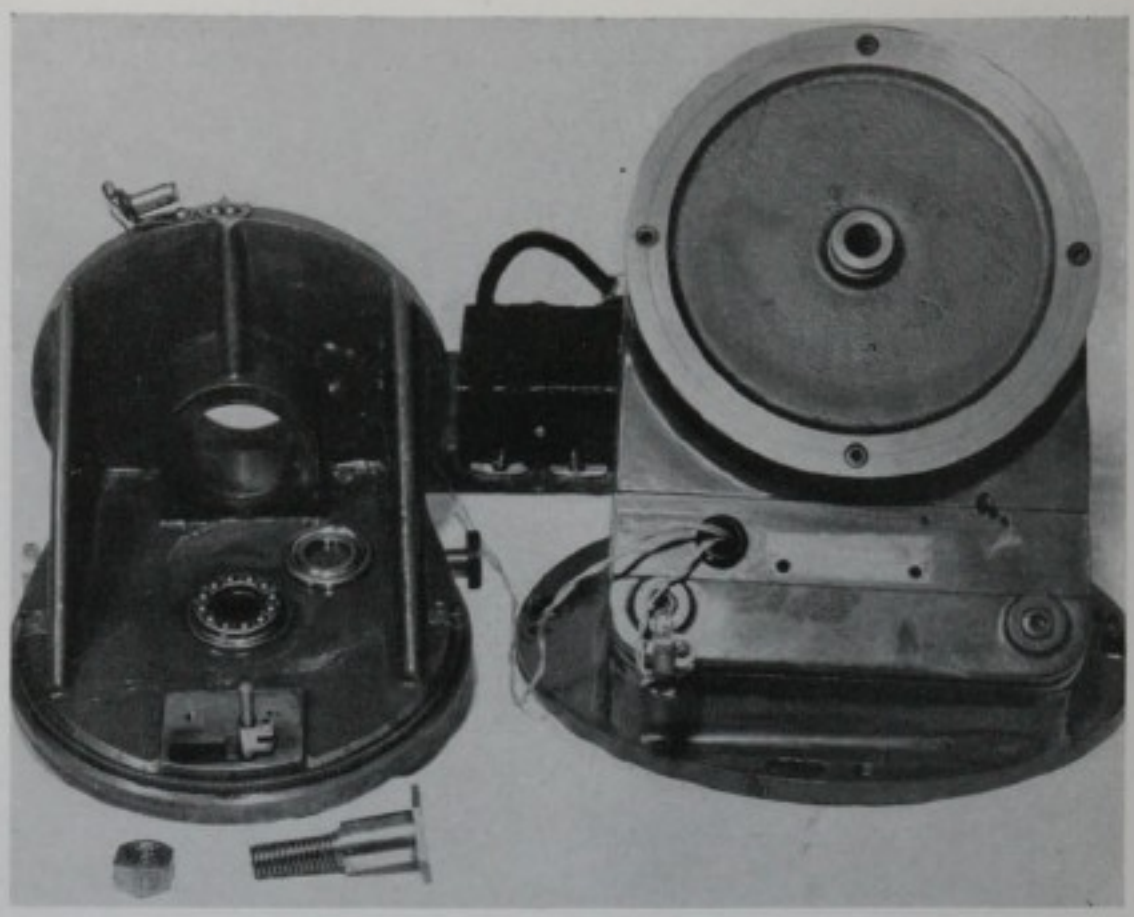

Fig. 18. The angle casting is at the left, with some of its adjoining parts. At the right is the base casting, with the ring casting in place.

it is the ball-bearing assembly for the polar-axis bolt, with its upper bearing ring removed to show the balls in their race. Farther front are the places for the vernier control, the slip-ring setting circle, and the worm gear. Lying in front of the assembly is the alloy-steel polar-axle bolt with its locking nut; this vital part holds the telescope and angle mounting to the base casting. The hole for the stud bolt is seen in the center of the ring casting (right), which has a central projection over which the worm gear is fitted. Behind the two castings is a black switch box for the electrical controls that are mounted on the south end of the angle casting.

The top of the worm gear is shown in Fig. 19, and it was seen last month in an oblique view (Fig. 13). The first ring out from the center hole is one of the principal bearing surfaces for the angle-plate assembly. The next ring is slightly lower than the first and provides a channel for the top plate of the clutch-locking unit. Outside of this ring is the recessed channel for the lower plate of the clutch, which is placed in the groove through the hole in this section located at the top of the picture.

The next bearing surface is for the clutch lock and is located on the same level as the surface on the other side of the clutch lock channel. There are scorings in this surface caused by serrations in the clutch plates when they are tightened during guiding. A very thin raised ring surrounds the surface just mentioned and provides the edge bearing surface for the angle plate. Finally, the slip-ring setting circle is mounted in another recessed groove, but it can be removed as a thin metal ring independently of the worm gear.

Fig. 19. The worm gear and clutch locking unit.

The bearing surfaces on the under side of the angle casting are clearly revealed in Fig. 20. In the center is the hole for the polar-axle bolt, and below this opening are two small holes through which pass the bolts that fasten the case for the clutch and vernier attachment to the upper side of this part of the angle casting. This area, from the central hole to just beyond these holes, is raised above the actual bearing surfaces, the wider one of which adjoins it. A recessed channel for the clutch lock is next, with the opening at the bottom through which the unit passes to the lock nut and vernier motion. The final bearing surface, a rather narrow one in comparison to the other, is raised along the outside edge

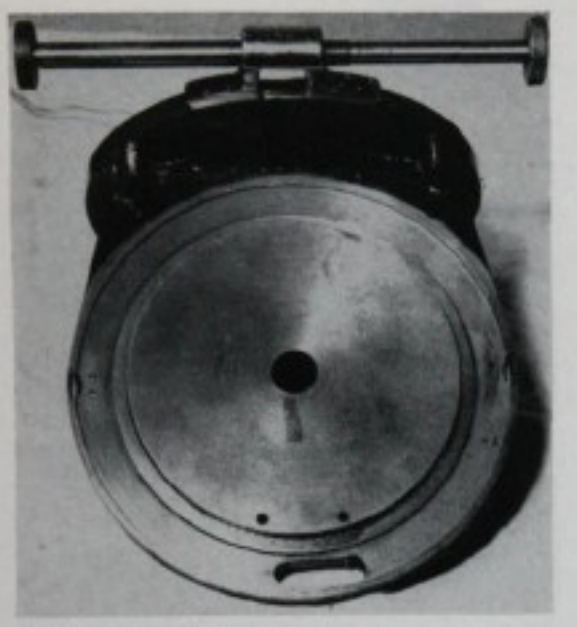

Fig. 20. The lower surface of the angle casting.

of the casting and machined so it is in the same plane as the wide inner one.

The present appearance of the assembled equatorial head is shown in Fig. 21. Note particularly the limit switch, located below the angle casting and on the far side of the right-ascension worm and control. When the telescope reaches the meridian, the edge of the angle casting presses downward on the protruding switch and stops the driving motor.

For celestial photography, the polar axis must point accurately at the celestial pole, and the provision for this is seen in the lower left of the picture. On the near side of the pier is a stud with a hexagonal head, which fits in a wide notch in a bracket attached to the bottom of the base casting. Long opposing bolts engage this stud; together with similar bolts on the opposite side of the pier they provide for accurate adjustment of the mounting base's position in azimuth.

Note the pairs of vertical bolts on the north and east sides of the mounting base. The action of these was described last month in connection with Fig. 7. One bolt of each pair passes through a slot in the mounting base into the pier plate; the other presses against the pier plate and can be turned to raise or lower the mounting, for east-west leveling and latitude adjustment. Out of view in the picture are two similar pairs of bolts on the south and west sides of the pier.

Since completing his basic telescope, Dr. Custer has experimented with several kinds of celestial photography, and for this has made further additions and modifications to his instrument. In the near future, these changes will be described in this department and examples of his photographs presented.

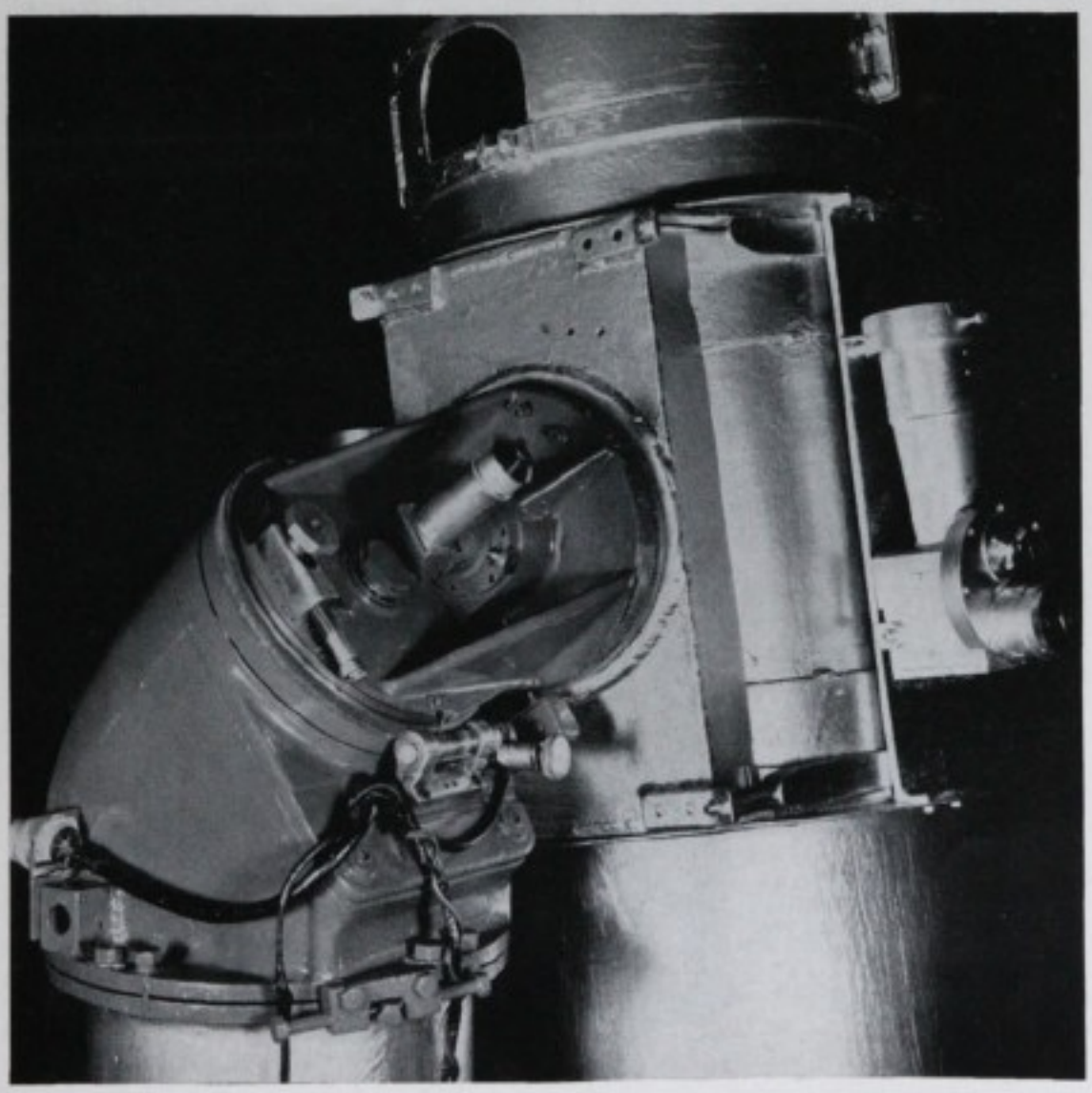

Fig. 21. In this recent photograph of the heart of Dr. Custer's Springfield reflector, modifications made for celestial photography are seen. But the design is essentially unchanged, the picture showing how the tube is attached and is supported by the equatorial head that has been described in this article.

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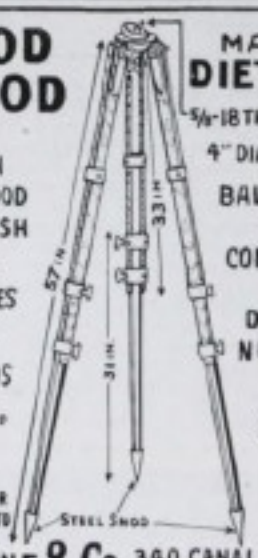

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WAR-SURPLUS TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. 2 achromats, F.L. 28-mm., eye relief 22-mm. An extension added, O.D. 1¼", standard for all types of telescopes. Govt. cost $24.50.

Stock #5223-Y ..... $7.95 ppd.

EDSCORP SATELLITE TELESCOPE

THE STORY: From the beginning of the visual satellite program, Edmund Scientific Co. was consulted by the Coordinator of Visual Satellite Observations of the Smithsonian Astrophysical Observatory in order to find existing optical instruments or to help in the development of new ones to meet the unique requirements of MOONWATCH. Every effort was to be made to get an instrument with the greatest possible field, which would still have the ability to observe faint objects with only slight magnification. All this was to be provided at a minimum cost. More than thirty different optical arrangements were examined and evaluated by expert advisors to the MOONWATCH program. The optics which we have used have been described in the *Bulletin for Visual Observers of Satellites* as providing the best combination for the purpose.

OPTICS: The Satellite Scope has two important optical characteristics: A wide (51-mm.) diameter, low-reflection-coated objective lens. A six-element extremely wide field, coated Erfle eyepiece that, in combination with the objective, gives 5.5 power with a big 12° field and over 7-mm. exit pupil.

MOUNT: The mount came in for special attention because of unique requirements of group observing. The center of rotation of the instrument is just below the point where the optical axis is deflected by the front-surface mirror. The mirror is set at 45° to the axis of the telescope barrel and reflects light at exactly 90°. Side brackets and wing nuts permit fast, easy elevation and rigid locking. Rubber eyeguards and the angle of the telescope permit the greatest comfort in long-time viewing. The wide field and our special mount permit the utmost coverage of the possible passage of the satellite without omission of an area of the sky by a string of observers.

OTHER USES FOR THE SATELLITE SCOPE

1. Makes a perfect wide-field finder. A special groove on the barrel helps in locating it in the finder mount. Fits our twin-ring finder mount, Stock No. 70,079-Y—$9.95. 2. Use the Erfle eyepiece on your regular astronomical telescope. You will need our adapter, Stock No. 30,171-Y—$3.95, which gives you an O.D. of 1¼". This eyepiece cost the government $56.00! 3. Makes a wonderful comet seeker; see complete asterisms. 4. Makes a fine rich-field telescope; see wide areas of sky with deep penetration.

Especially Made for Members of MOONWATCH
Stock #70,074-Y ..... $49.50 ppd.

ATTENTION!

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If you want to build your own Satellite Scope, we can supply the optical parts, or any metal parts from our assembled Satellite Scope. We'll be glad to send you full description of these components together with price information.

WRITE FOR SATELLITE BULLETIN #40-Y

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth.	Description	Price
80,038-Y	4⅜"	5¼"	46"	Spiral-wound paper	$2.50
85,008-Y	6⅞"	7⅜"	60"	Spiral-wound paper	4.00
85,011-Y	2⅞"	3"	48"	Aluminum	6.00
85,012-Y	3⅞"	4"	60"	Aluminum	8.75
85,013-Y	4⅞"	5"	48"	Aluminum	9.00
85,014-Y	6⅞"	7"	60"	Aluminum	15.00

All tubing is shipped f.o.b. Barrington, N. J.

EDMUND SCIENTIFIC CO.

WAR-SURPLUS KELLNER EYEPIECE

Mounted — Ready to Use — 1¼" Outside Diameter — Coated — 1¼" Focal Length

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Stock #50,130-Y ..... **$5.90 ppd.**

Rack & Pinion Eyepiece Mounts

For Reflectors

For Refractors

Now you can improve performance in a most important part of your telescope — the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these fine features: real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting; focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅝" I.D. and our 3⅝" I.D. aluminum tubes respectively.

Stock #50,077-Y (less diagonal holder) $9.95 ppd.
Stock #60,035-Y (diagonal holder only) 1.00 ppd.
Stock #50,103-Y (for 2⅜" I.D. tubing) 12.95 ppd.
Stock #50,108-Y (for 3⅜" I.D. tubing) 13.95 ppd.

HUYGENS EYEPIECES

Here are some really terrific values in eyepieces! The three eyepieces listed below are manufactured by one of the world's best producers of optical components. We have searched the world's markets, including Germany and France, to find a real quality eyepiece. The image clarity, the workmanship evidenced in the metal parts, will prove the skill and experience of Goto Optical Company, Tokyo. Guaranteed terrific buys!

HUYGENS TYPE — STANDARD 1¼" DIAM.
6-mm. (¼") Focal Length
Stock #30,063-Y ..... **$8.50 ppd.**

12.5-mm. (½") Focal Length
Stock #30,064-Y ..... **$8.00 ppd.**

COMBINATION EYEPIECE — 10-mm. and 20-mm.
Stock #30,065-Y ..... **$9.00 ppd.**

7X — FINDER TELESCOPE — ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts **$9.95**

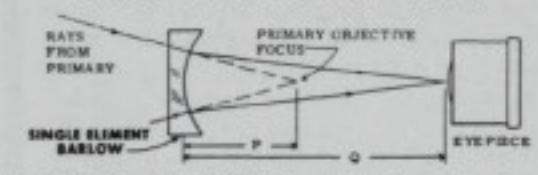
Stock #50,075-Y Ring mounts per pr., **$3.95**

HEAVY-DUTY EQUATORIAL MOUNT AND TRIPOD for 6"-8" REFLECTING TELESCOPE

Heavy cast base with sturdy 32" long hardwood legs. 1" shafts. Boston bronze bearings to provide a uniform film of lubrication over entire bearing surface and assure smooth operation. Big locking knobs 1¾" on both declination and polar axes. Polar axis variable for latitude adjustment. 12" cradle securely holds 3" to 10" tubes. Beautifully finished in baked black crinkle paint. Legs can be removed easily for permanent post mounting. Height 38", weight 32 lbs.

Stock #85,023-Y ..... **$49.50 f.o.b.**

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER WITH A BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power. The new power of the telescope is not, as you might suppose, due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q!

Beautiful chrome mount. We now have our Barlow lens mounted in chrome-plated brass tubing with special spacer rings that enable you to vary easily the power by sliding split rings out one end and placing them in other end. Comes to you ready to use. Just slide our mounted lens into your 1¼" I.D. tubing then slide your 1¼" O.D. eyepieces into our chrome-plated tubing. Two pieces provided, one for regular focal length eyepieces and one for short focal length ones.

Remember, in addition to doubling and tripling your power, a Barlow lens increases your eye relief and makes using a short focal length eyepiece easier.

Don't fail to try one of these. Many people do not realize the many advantages of a Barlow and the much greater use they can get from their telescopes. Our Barlow has a focal length of −1 5/16". We have received many complimentary letters about this lens. So sure are we that you will like it that we sell it under a 30-day guarantee of satisfaction or your full purchase price returned — no questions asked. You can't lose, so order today.

Stock #30,200-Y Mounted Barlow lens $8.00 ppd.

ATTENTION—BEGINNERS AND JUNIOR ASTRONOMY CLUBS

To solve the problem of low-cost lenses of good quality for a beginner's telescope we have had these achromatic lenses designed and mass produced. Our first shipment is in. They are swell!

ACHROMATIC OBJECTIVE, 32-mm. diam. (1¼"), F.L. 31", (Will get 62X with ½" eyepiece; 124X with ¼" eyepiece)
Stock #30,201-Y ..... **$2.50 ppd.**

ACHROMATIC OBJECTIVE, 42-mm. diam. (1 21/32"), F.L. 41", (Will get 41X with 1" eyepiece; 82X with ½"; and 164X with ¼")
Stock #30,202-Y ..... **$4.00 ppd.**

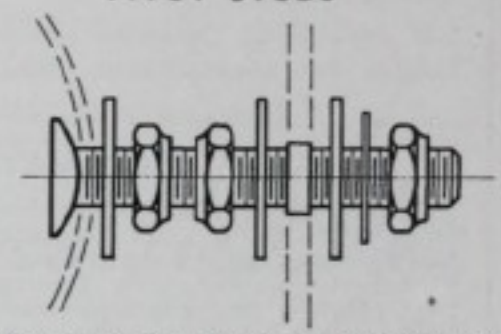
UNMOUNTED SETS OF RAMSDEN EYEPIECE LENSES
Stock #30,210-Y ..... **½" eyepiece set** **$1.50**
Stock #30,208-Y ..... **¼" eyepiece set** **$1.75**

PRISM STAR DIAGONAL

For comfortable viewing of the stars near the zenith or high overhead on refractor telescopes using standard size (1¼" O.D.) eyepieces, or you can make an adapter for substandard refractors. Contains an excellent quality aluminized right-angle prism. Tubes are satin chrome-plated brass. Body is black wrinkle cast aluminum. Optical path of the system is about 3½".

Stock #70,077-Y ..... **$12.00 ppd.**

PIVOT STUDS



Complete set of Pivot Studs for mounting any tube in a yoke. Self-locking nuts, flat and spring washers. Fits our Stock #85,042-Y, described on opposite page.

Stock #30,218-Y ..... **$3.95 ppd.**

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

The same fine mirror as used in our Palomar, Jr., polished and aluminized, lenses for eyepieces and diagonal. No metal parts.

Stock #50,074-Y ..... **$16.25 ppd.**

8X FINDER TELESCOPE

Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm. diam. objective. Weighs less than ½ pound.

Stock #50,121-Y ..... **$8.00 ppd.**

MISCELLANEOUS ITEMS

KELLNER EYEPIECE — 2" focal length (1¼" O.D.). Mount of black anodized aluminum.
Stock #30,189-Y ..... **$6.00 ppd.**

60° SPECTROMETER PRISM — Polished surfaces 18-mm. x 30-mm. — flat to ½ wave length.
Stock #30,143-Y ..... **$8.25 ppd.**

BRASS TUBING

2 pieces, 3" long, slide fitting. Blackened brass. I.D. 1-3/16", O.D. 1-5/16".

Stock #40,165-Y ..... **$1.75 ppd.**

30-day Money Back Guarantee as with all our Merchandise!

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We offer the lowest priced, hand-corrected, precision, American-made astronomical objective, *mounted in a black anodized aluminum cell*. Our reputation has been established over the years as the most reliable source of high quality astronomical lenses.

"Those in the know" BUY FROM US BECAUSE:

Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" f.l. (uncoated).. **$28.00** — Same as above with coating..... **$32.00**

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We can supply ALUMINUM TUBING for the above lenses.

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We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm (2⅛")	254 mm (10").....	$12.50	83 mm (3¼")	660 mm (26").....	$28.00
54 mm (2⅛")	300 mm (11.8").....	12.50	83 mm (3¼")	711 mm (28").....	28.00
54 mm (2⅛")	330 mm (13").....	12.50	83 mm (3¼")	762 mm (30").....	28.00
54 mm (2⅛")	390 mm (15.4").....	9.75	83 mm (3¼")	876 mm (34½").....	28.00
54 mm (2⅛")	508 mm (20").....	12.50	83 mm (3¼")	1016 mm (40").....	30.00
54 mm (2⅛")	600 mm (23½").....	12.50	102 mm (4")	876 mm (34½").....	60.00
54 mm (2⅛")	762 mm (30").....	12.50	108 mm (4¼")	914 mm (36").....	60.00
54 mm (2⅛")	1016 mm (40").....	12.50	110 mm (4⅓")*	1069 mm (42⅛").....	60.00
54 mm (2⅛")	1270 mm (50").....	12.50	110 mm (4⅓")	1069 mm (42⅛").....	67.00
78 mm (3⅛")	381 mm (15").....	21.00	128 mm (5⅛")*	628 mm (24¾").....	75.00
80 mm (3⅛")	495 mm (19½").....	28.00	128 mm (5⅛")	628 mm (24¾").....	85.00
81 mm (3⅜")	622 mm (24½").....	22.50	*Not coated		

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COATED BINOCULARS

American Type — Zeiss Type

Beautiful imported binoculars, precision made, at a low, low price. Above we have pictured the two most popular types. The American Type offers a superior one-piece frame and a clean design, pleasing to the eye. Complete with carrying case and straps. **Price plus 10% Federal tax.**

SIZE	TYPE	C. FOCUS	IND. FOCUS
6 x 15	OPERA	—	$12.75
6 x 30	ZEISS	$18.75	16.75
7 x 35	ZEISS	21.25	19.25
7 x 35	AMERICAN	23.50	—
7 x 35	AMERICAN WIDE ANGLE 10°	37.50	—
7 x 50	ZEISS	24.95	22.50
7 x 50	AMERICAN	32.50	—
8 x 30	ZEISS	21.00	18.25
10 x 50	ZEISS	30.75	28.50
20 x 50	ZEISS	41.50	39.50

MONOCULARS

Brand new, coated optics, complete with pigskin case and neck straps.

	Price		Price
6 x 30	$10.00	7 x 50	$15.00
8 x 30	11.25	16 x 50	17.50
7 x 35	12.50	20 x 50	20.00

"MILLIONS" of Lenses, etc. Free Catalogue

We pay the POSTAGE — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

"GIANT" 3" TELESCOPE

40 power Special Price **$57.50**

Never before has anything like this been offered at so low a price. Here is another example of American ingenuity. Big 3" diameter achromatic coated objective which will give needle-sharp crystal-clear images. Focusing is a delight with the micrometer spiral focusing drawtube. Light-weight aluminum construction throughout, black crackle finish, length open 22 inches, closed 17 inches. This telescope gives an upright image—it is WONDERFUL for astronomy, SUPERB for long distances, EXCELLENT as a spotting scope.

"GIANT" EYEPIECE

WIDE ANGLE ERFLE (68° Field) **EYEPIECE.** Brand new coated 1¼" E.F.L. Focusing mount. 3 perfect achromats, 1⅜₁₆" aperture. **$12.50**

WIDE ANGLE ERFLE 1¼" E.F.L. Brand new; contains Eastman Kodak's rare-earth glasses; aperture 2"; focusing mounts; 65° field.. **$18.50**

1¼" **Diam. Adapter** for above eyepieces. **$3.95**

LENS CLEANING TISSUE — Here is a wonderful Gov't. surplus buy of Lens Paper which was made to the highest Gov't. standards and specifications.

500 sheets size 7½" x 11"..... **$1.00**

MOUNTED EYEPIECES

The buy of a lifetime at a great saving. Perfect war-surplus lenses set in black anodized standard aluminum 1¼" O.D. mounts.

F.L.	TYPE	PRICE
12.5 mm (½")	Symmetrical.....	$ 6.00
16 mm (⅝")	Erfle (wide angle).....	12.50
16 mm (⅝")	Triplet.....	12.50
18 mm (¾")	Symmetrical.....	6.00
22 mm (²⁷/₃₂")	Kellner.....	6.00
32 mm (1¼")	Orthoscopic.....	12.50
35 mm (1⅜")	Symmetrical.....	8.00
55 mm (2⅛")	Kellner.....	6.00

COATED 75 cents extra.

ASTRONOMICAL MIRRORS

These mirrors are of the highest quality, polished to ¼-wave accuracy. They are aluminized, and have a silicon monoxide protective coating. You will be pleased with their performance.

	Diam.	F.L.	Postpaid
Plate Glass	3³/₁₆"	42"	$ 9.75
Pyrex	4¼"	45"	$13.50
Pyrex	6"	60"	$25.00

AN ECONOMICAL EYEPIECE

This mounted eyepiece has two magnesium-fluoride coated lenses 29 mm in diameter. It is designed to give good eye relief. It has an effective focal length of 1¼" (8x).

The eyepiece cell fits a 1¼" tube..... **$4.50**

Aluminum Telescope Tubing

O.D.	I.D.	Price Per Ft.
2¼"	2⅛"	$1.20
3¾"	3½"	1.75
4½"	4⅜"	2.75
5"	4⅞"	2.75

All tubing is shipped POSTPAID.

Focusing Eyepiece Mounts Rack & Pinion Type

The aluminum body casting is finished in black crackle paint and is machined to fit all our aluminum tubing. Has a chrome-plated brass focusing tube, which accommodates standard 1¼" eyepieces.

For 2⅛" I.D. Tubing	Postpaid	$12.95
For 3½" I.D. Tubing	"	12.95
For 4⅜" I.D. Tubing	"	12.95

Reflector type for all size tubing.

Complete with diagonal holder..... $ 9.95

Aluminum Lens Cells Black Anodized

Cell for Lenses	Cell Fits Tubing	Price
54 mm Diam.	2⅛" I.D.	$ 3.50
78 mm "	3¼" "	6.50
81 mm "	3¼" "	6.50
83 mm "	3¼" "	6.50
110 mm "	4⅜" "	10.50

3X TELESCOPE

Makes a nice low-priced finder. Brand new; has 1" Achromatic Objective. Amici Prism Erecting System. 1¾" Achromatic Eye and Field Lens. Small, compact, wt. 2 lbs.

Gov't. Cost $200. **$9.75**

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Size	Thickness	Postpaid
14" x 16"	¼"	$10.00
8" x 10"	¼"	4.25
4" x 5"	¼"	1.85
4" x 4"	¼"	1.50
1¼" x 1½"	¼₁₆"	.25

RIGHT-ANGLE PRISMS

8 mm face.....ea.	$ .75	28 mm face.....ea.	$1.75
12 mm face.....ea.	.75	38 mm face.....ea.	2.00
23 mm face.....ea.	1.25	47 mm face.....ea.	3.00

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Observations of the November Total Eclipse of the Moon

GOOD WEATHER over most of the United States on the night of last November 17-18 allowed widespread amateur observations of the lunar eclipse, both photographic and visual. Clear skies prevailed in the South and West, but the Middle West was partly cloud covered, and watchers in the northeastern states were foiled by overcast, rain, and snow.

Many amateurs organized eclipse parties, especially societies on the Pacific Coast, where the passage of the moon through the earth's shadow occurred during convenient evening hours. On page 143 are tabulated the names of more than 50 correspondents who sent in reports and photographs. This list includes the other persons in each observing party, if their names were listed by the correspondent, but some may have been inadvertently overlooked in perusing the longer, detailed reports. In this article, observers are mentioned by name only; their geographical locations may be found in the list.

Probably this was one of the most-photographed lunar eclipses on record, and a selection from hundreds of pictures submitted to *Sky and Telescope* appears on pages 112 to 114 of this issue. It will not be possible to publish the many other excellent prints that are very similar to those we have used. The photographic work was of generally high quality, and some amateurs achieved remarkable results with simple equipment.

The noteworthy material selected from the many visual reports of the varied phenomena of the eclipse can be easily fitted into a unified pattern. On eclipse night, the dark, conical inner shadow of the earth was 1° 06′ in diameter at the moon's distance from the earth, and the diameter of the outer shadow or penumbra was 2° 30′. Sunlight filters through the earth's atmosphere into the shadow, giving a steeper and steeper drop in brightness from the outer edge of the penumbra to the center of the shadow. We can regard the moon, 32 minutes of arc in diameter, as a probe passing through the shadow; by observing the brightness and hue of the moon during the eclipse we can determine the distribution of light and color inside the shadow.

The first visible evidence of the eclipse was the faint darkening of the eastern edge of the moon by the penumbra. This shading was generally described as grayish or smoky in tint. How long before the beginning of umbral eclipse was this darkening detectable? D. Morrison saw it 38 minutes before that time, and F. Pilcher's 3½-inch reflector showed it 35 minutes before. R. Cuffey could see penumbral darkening in his 7-inch reflector

Shortly before the eclipse began, the clouds disappeared to give fine conditions for photographic and visual observations at Chicago's Adler Planetarium and Astronomical Museum. Seen here on the museum terrace are, left to right, James Caplan, Dr. Albert Shatzel, Richard Monnier, Steve Zarlenga, Henry Hudson, and Paul Lind.

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Elliptical shape
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BERAL COATINGS — same optical characteristics as aluminum — mechanically more durable — not over-coated — may be removed without harming glass surface. Prices for Beral coating telescope mirrors: 4" diam.- $2.75, 6"- $3.50, 8"- $4.50, 10"- $6.50 and 12½"- $9.75 each, f.o.b. Skokie.

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Dual Finder that swings to either side of eyepiece. Find object with ease, east or west of your meridian.

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at 4:34 UT, and 12 minutes later it was easily visible to the naked eye. He was also able to see the penumbra until 35 minutes after the end of umbral eclipse.

During the partial stages of the eclipse, the visible part of the penumbral shading formed a border to the umbra about 10 minutes of arc in width, according to estimates by F. Kosdon and Cuffey.

While the partial eclipse was progressing, many observers noted that the umbra presented a distinct structure. C. Holton's records show that in his 6 x 57 binoculars the outer zone of the umbra was light gray, surrounding a light rosy copper area which deepened into copperish red at the center of the shadow. This outer umbral zone, which was about five minutes of arc wide, was described as grayish (Pilcher, 3½-inch reflector), dull gray (J. Tanner and E. Randall), slate gray (Cuffey), and yellow gray (Kosdon, 10-inch reflector).

There was good general agreement among the descriptions of the color of the moon near mid-totality, when it was most deeply immersed in the umbra: bright orange (Pilcher), copper (E. Brewer), red copper (Tanner and Randall), dark copper (H. Klink), strong red like Mars (B. Gilligan, 7 x 50 binoculars), and blood red (D. Morrison).

It was not an unusually dark eclipse, most observers agreed. In moderate-sized telescopes, the lunar seas and principal craters remained distinctly visible during totality. At mid-eclipse, the seas could be seen by Holton in binoculars, and by Kosdon in a 1-inch finder. As explained on page 39 of the November issue, Willard J. Fisher has classified lunar eclipses on a scale of *2*, bright; *1*, intermediate; and *0*, dark. On this system, the eclipse of November 17-18, 1956, seems best described as intermediate between *1* and *2*.

Several observers reported that no craters were visible, but in each of these cases haze or other unfavorable sky conditions were mentioned in the report.

It has been found at previous eclipses that the umbra is always rather larger than would be predicted from the known sizes of the earth, sun, and moon, and the distances involved. The amount of this enlargement of the umbra can be derived from carefully observed times of the beginning and end of the partial or total stages of the eclipse. Several observers recorded such contact times for the November eclipse.

The results are summarized in the table, where contacts I, II, III, and IV refer, respectively, to the times of first entrance of the moon into the umbra, the beginning and end of totality, and the final emergence from the umbra. The second column

Above the totally eclipsed moon are the Pleiades, and to the left the Hyades, in a photograph by W. K. Hartmann, of New Kensington, Pennsylvania. He strapped a 35-mm. Leica camera to the tube of his 8-inch reflector, whose shadow is seen at the bottom. The hand-guided exposure had a duration of 10 minutes.

TRECKER SCOPES

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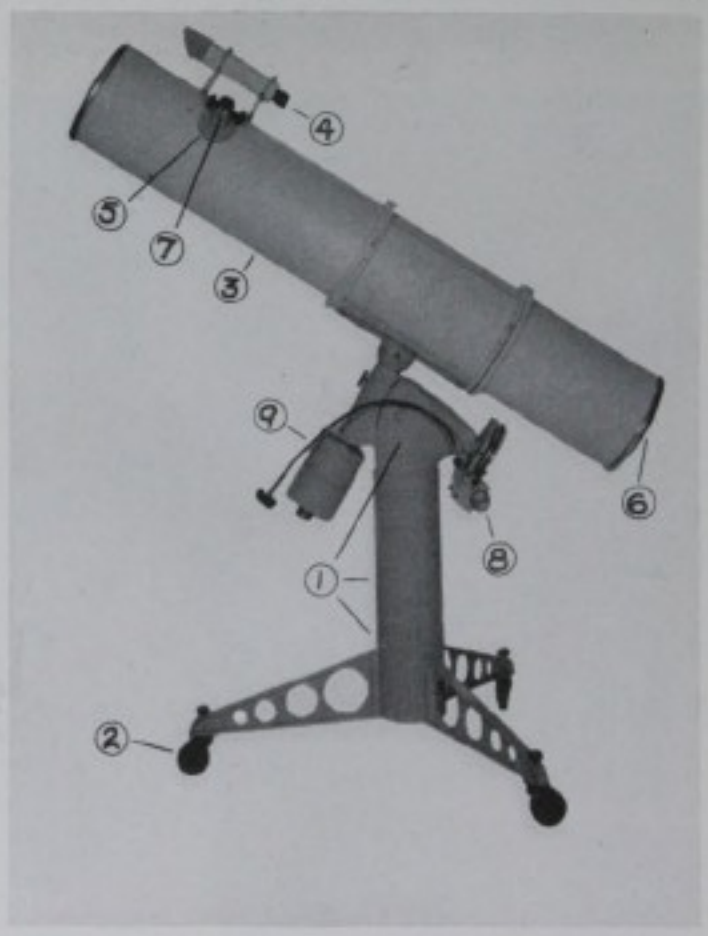

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From penumbral eclipse to totality, as recorded with an f/4.7 lens of 135-mm. focal length on Royal Pan film. R. B. Edmundson, Abilene, Texas, exposed at very nearly 10-minute intervals, starting about 11:10 p.m. CST.

tells the average of the observed times expressed in Universal time, and the third gives the number of observers. The fourth column indicates, in seconds of arc, the excess of the observed radius of the umbra over its computed value, and the last column expresses this excess as a fraction of the umbra's radius.

(1)	(2)	(3)	(4)	(5)
I	5:02.8	6	+56"	0.022
II	6:07.9	5	+67"	0.026
III	7:28.4	5	+81"	0.032
IV	8:32.6	4	+63"	0.024
			Mean	0.026

At the November 17-18 eclipse, therefore, the umbra was about 2.6 per cent larger than its geometrical value, according to these observations. This result is in rather good agreement with the two-per-cent enlargement that the *American Ephemeris* adopts in its predictions of lunar eclipses.

Several observers timed when conspicuous craters entered and left the umbra during this eclipse. These observations can also be used to evaluate the amount of enlargement of the earth's shadow, and the results are being analyzed.

The lunar eclipse was a phenomenon well worth watching, as an activity for amateur groups, and as an opportunity to spread interest in astronomy. And, as if to compensate the East Coast observers who were clouded out, there will be a return performance this May 13th, when the ending of the next lunar eclipse will be visible shortly after moonrise along the Atlantic seaboard. J. A.

LIST OF ECLIPSE CORRESPONDENTS

Photographs were received from those indicated by asterisks.

MIDDLE ATLANTIC STATES

New York: *C. Schell, Ithaca.
Pennsylvania: *W. Hartmann, New Kensington; *R. McLaughlin, New Kensington.
Virginia: *H. Klink, Roanoke.
West Virginia: *W. Bess, Jr., and H. Brubeck, Jr., Huntington.

MIDDLE WESTERN STATES

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Indiana: R. Cuffey, Bloomington; C. Hines, Dyer; *K. McAbee, Indianapolis.
Iowa: D. Cruikshank, Des Moines.
Kansas: F. Pilcher, Topeka.
Michigan: *G. Trotzuk, Detroit.
Missouri: *H. and D. Brown, Columbia.
Ohio: *D. Farnsworth, Columbus; *B. Gilligan, Akron.

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Arkansas: Mrs. H. Shoemaker, Fayetteville.
Florida: J. Tanner and E. Randall, Tampa.
Georgia: C. Holton, Atlanta.
North Carolina: *J. Franklin, Hendersonville; *K. Shepherd, Winston-Salem.
Tennessee: *J. Brown, Kingsport; *D. Geilker, Nashville; *K. McCorkle, Memphis.
Texas: E. Brewer, Dallas; *R. Edmundson, Abilene; *H. Swiggett, San Antonio; *K. Wagland, J. Hudson, and B. McMurray, Henderson.

WESTERN STATES

Arizona: *D. Strittmatter, Tucson.
California: *E. Bruner, Jr., China Lake; *J. Eastman, E. Edwards, B. Elliott, M. Gardner, K. Kokos, E. Punches, and G. Rawlins, Manhattan Beach; *O. Erpenstein, Millbrae; *M. Golub, L. Epstein, and W. Shopes, Berkeley; F. Kosdon, Buttonwillow; *R. Libby, San Jose; K. Marhenke, Berkeley; *L. Neufeld, Corona Del Mar; R. Perkins, Gardena; *P. Peters, Long Beach; *B. Peterson, D. Anderson, and G. Landry, San Jose; *D. Stanton, Santa Monica.
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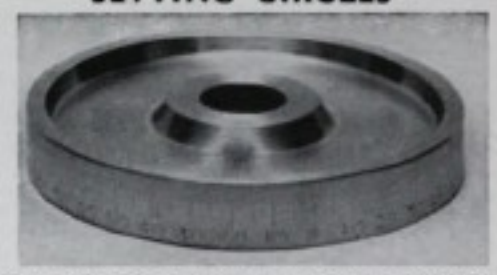

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AURORAL OBSERVATIONS

BRIGHT northern lights seen recently in Canada, Alaska, and widespread parts of the United States indicate that auroral activity is reaching a high level, as is to be expected when the number of sunspots is near an all-time high.

At Whittier, Alaska, a brilliant flaming aurora was seen during the morning hours of October 6th by the Rev. S. F. Maxwell, of Northlake, Illinois. Earlier that night there had been some typical ray activity in the eastern sky, but after 2:30 a.m., Alaska standard time, a large milky patch appeared in the east and southeast, reaching a fourth of the way up the sky. Half an hour later this patch quickly brightened and became pale green and blue. Brilliant flashes of light traveled upward from it, disappearing near the zenith, at a rate of two or three pulses per second. He describes the 50-minute activity as having "wave on wave like water lapping at the beach," but after 4 a.m. dawn put an end to his observations.

A major display occurred on Saturday night, November 10-11, and was seen by amateurs in New England, including the Boston area. Frank J. DeKinder, director of observations of the Montreal Centre, Royal Astronomical Society of Canada, has sent a detailed report. As soon as darkness fell, the aurora was evident, and it was watched by one or another of the society's members until 2 a.m. The description is condensed mainly from the reports of Mrs. C. Zorgo, Miss I. Williamson, and C. E. Gallagher.

A homogeneous arc, extending from northeast to northwest early in the evening, soon was the source of streamers that reached almost to the zenith. They were of increasing intensity and light green in color. By 11 p.m., Eastern standard time, an irregular corona had developed near the zenith, while draperies of colors from light green to rose covered most of the sky. Toward 1 a.m., darts of deep red were added to the spectacle, which soon diminished in intensity, but it is believed to have lasted all night.

On the morning of Thursday, November 14th, shortly after 5 o'clock, L. B. Stark observed a bright aurora at Upper Montclair, N. J. It was characterized by the occasional appearance of colorful rayed arcs, covering most of the northern sky and extending to the zenith. The display closed about 5:30 a.m.

At Victoria, B. C., while observing the eclipse of the moon on November 17th through a partly cloudy sky, Harry L. Bondy (of New York City) and Robert S. Evans saw very bright auroral rays, which lasted for only 10 minutes beginning at 11:10 p.m., Pacific standard time.

VARIABLE STAR MAXIMA

January 1, S Ursae Majoris, 123961, 7.9; 4, R Reticuli, 043263, 7.7; 4, RT Cygni, 194048, 7.4; 7, S Canis Minoris, 072708, 7.5; 20, S Herculis, 164715, 7.6; 27, V Cancri, 081617, 8.0; 29, V Ophiuchi, 162112, 7.5.

February 1, R Aurigae, 050953, 7.8; 2, R Octantis, 055686, 7.9; 8, RU Sagittarii, 195142, 7.2.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Palma, 372, 9.6. January 22, 10:30.2 +12-48. February 1, 10:20.7 +12-09; 11, 10:09.6 +11-32; 21, 9:58.0 +10-58. March 3, 9:47.1 +10-22; 13, 9:38.0 +9-45.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MINIMA OF ALGOL

January 2, 11:41; 5, 8:30; 8, 5:19; 11, 2:08; 13, 22:57; 16, 19:46; 19, 16:36; 22, 13:25; 25, 10:15; 28, 7:04; 31, 3:03. February 3, 0:42; 5, 21:31.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

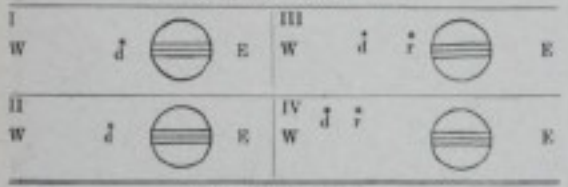
JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.

JANUARY

Phases of the Eclipses of the Satellites



Configurations at 0h UT

OCCULTATION PREDICTIONS

January 3-4 **Nu Aquarii** 4.5, 21:07.3 −11·32.8, 3, Im: **H** 2:28.1 −0.4 +0.4 45.

January 6-7 **Kappa Piscium** 4.9, 23:24.7 +14·01.2, 6, Im: **H** 4:05.7 −0.9 0.0 59; **I** 4:18.0 . . . . . 359.

January 13-14 **Chi**[1] **Orionis** 4.6, 5:51.8 +20·16.2, 13, Im: **H** 10:48.5 −0.4 −1.5 109; **I** 10:29.0 −0.8 −1.0 79.

January 16-17 **Alpha Cancri** 4.3, 8:56.1 +12·01.5, 16, Im: **H** 8:37.7 −2.8 +1.9 64. Em: **H** 9:25.6 −0.6 −3.6 348.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**LO** − **LoS**), and multiply **b** by the difference in latitude (**L** − **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

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B	+73°.6,	+45°.5	**F**	+98°.0,	+31°.0
C	+77°.1,	+38°.9	**G**	Discontinued	
D	+79°.4,	+43°.7	**H**	+120°.0,	+36°.0
			I	+123°.1,	+49°.5

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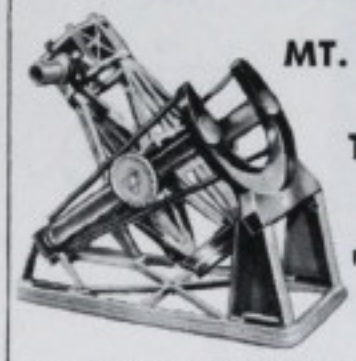

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Venus above Jupiter in the dawn sky on October 25th, a few hours before the planets' closest approach. Photo by Peter Leavens.

VENUS-JUPITER CONJUNCTION OBSERVED OCTOBER 25TH

Amateurs in many parts of the country successfully observed the conjunction of Venus and Jupiter in the morning sky on October 25, 1956, when the brightest planet passed only 13 minutes of arc north of the largest planet. Owing to their greatly differing distances from the earth, however, the angular diameter of Venus was about half that of Jupiter.

At Jones Beach, New York, Peter Leavens observed the event with Zeiss 15 x 50 binoculars; he also photographed the dawn scene.

A 10-inch Astrola reflector and 32-mm. eyepiece were used by Dick Stanton, of Santa Monica, California, for a dozen photographs showing Venus and Jupiter as disks in the same field. After the light of dawn made photography impossible, he was able to fit both planets into the same field of view, using 210x.

At Napa, California, from his sleeping porch Frank Trathen saw the two planets rise together about 3:30 a.m. Through his 4-inch refractor it was difficult to detect Jupiter's satellites I and IV because of the glare from Venus.

Dr. J. R. Otoupalik, at Greeley, Colorado, took advantage of the occasion to see Venus by daylight; then he observed nearby Jupiter with a 6x finder. In 16x binoculars the two planets were a beautiful sight.

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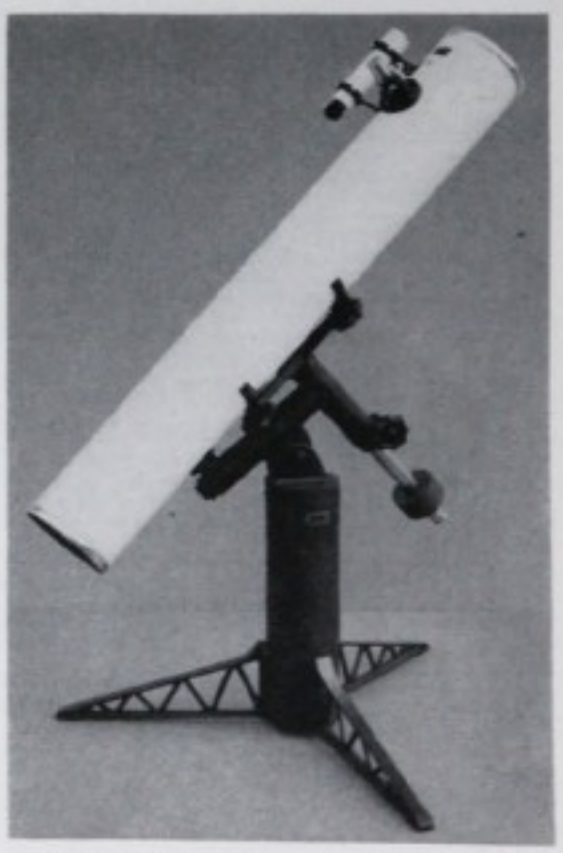

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DEEP-SKY WONDERS

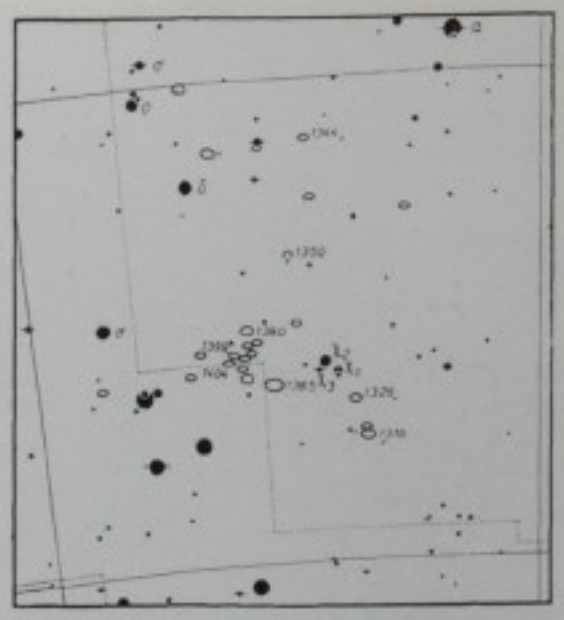
READERS who have enjoyed Harlow Shapley's *Galaxies* will recall his account of the Fornax group, and those who have looked up the region in the Skalnate Pleso *Atlas of the Heavens* find a dense swarm of spirals. But most people do not realize that this amazing group is within the reach of an observer in latitude 40° north, if he has a fine, clear sky near the southern horizon. It is worth watching for a perfect night so that this tightly clustered group may be viewed at its best on the meridian, early these January evenings. Were this array in northern declinations, it would be one of the great shows of the sky.

Even so, a clear sky will show so many galaxies fainter than the 13th-magnitude limit that identifications are almost impossible, and the amateur must satisfy himself with the spectacle of unnamed wonders.

Half a dozen of these galaxies are brighter than magnitude 11.5 and hence visible in small telescopes; they are comparable with the fainter Messier objects. The brightest is 10th-magnitude NGC 1316, easy in a 3-inch. John Herschel described it in 1837 as "very bright, very large, 4′ in diameter, brightening first gradually and then suddenly toward the middle to a starlike nucleus." His description still holds for my 10-inch reflector in Kansas.

Just north of NGC 1316 lies 12th-magnitude NGC 1317 (plotted but not numbered in the Skalnate Pleso atlas). A large telescope and a fine night will bring out faint NGC 1318 between the two; a 10-inch shows the last with difficulty.

Another major attraction in the Fornax grouping is NGC 1365, a large 11th-magnitude spiral fully 8′ long, which can be observed even with a 3-inch. With its obviously lenticular form and bright central part, it reminds one of binocular views of M31.



Portions of the constellations Eridanus (left) and Fornax, reproduced from the Skalnate Pleso atlas, in which galaxies are represented as ellipses. The upper and lower lines are the 30° and 40° parallels of south declination. This area was first searched for nebulae and clusters by James Dunlop in Australia 130 years ago.

The galaxies brighter than photographic magnitude 12.5 in the Fornax region are listed here, with their positions for 1950. Their types are abbreviated: E, elliptical; S, spiral; SB, barred spiral.

NGC	Right Ascension h m	Declination ° ′	Mag.	Size ′ × ′	Type
1291	3 15.5	−41 17	10.2	5.0 × 2.0	E
1316	3 20.7	−37 25	10.1	3.5 × 2.5	S
1317	3 20.8	−37 17	12.2	0.7 × 0.6	S
1326	3 22.0	−36 39	11.8	3.0 × 2.5	SB
1365	3 31.8	−36 18	11.2	8.0 × 3.5	SB
1374	3 33.4	−35 24	12.4	0.8 × 0.8	E
1379	3 34.2	−35 37	12.3	0.6 × 0.6	E
1380	3 34.6	−35 09	11.4	3.0 × 1.0	E
1386	3 35.0	−36 10	12.4	2.5 × 1.0	S
1387	3 35.1	−35 41	12.1	1.0 × 0.9	E
1399	3 36.6	−35 37	10.9	1.4 × 1.4	E
1404	3 37.0	−35 45	11.5	1.0 × 1.0	E
1427	3 40.4	−35 34	12.4	2.0 × 1.3	E

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UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

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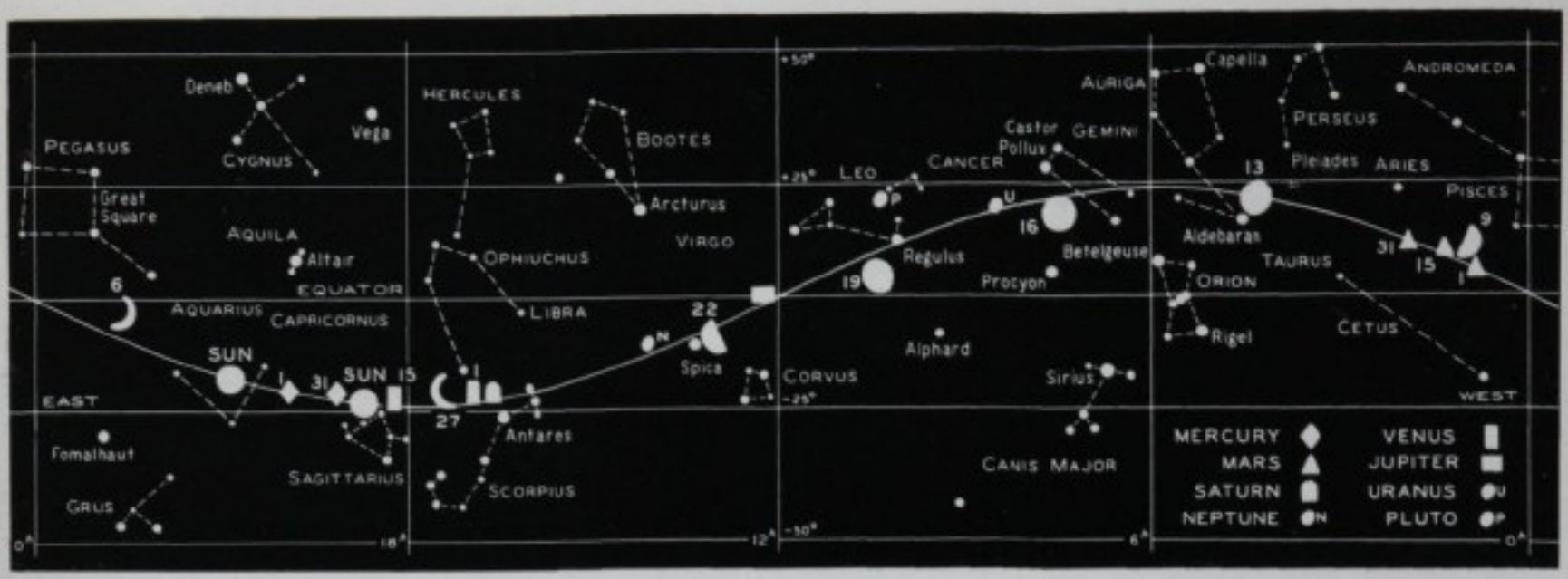

THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown.

Mercury does not become easily visible until the end of January. The smallest principal planet passes inferior conjunction with the sun on January 10th, entering the morning sky. It then moves rapidly to greatest western elongation on February 2nd. In the last week of the month, Mercury can be observed rising 1½ hours before the sun at near zero magnitude.

Venus rises slightly more than an hour before the sun, its 10″.9-diameter disk 93-per-cent illuminated and shining at magnitude −3.3 on the 15th of the month. On the 21st Venus will pass 2° 42′ south of Mercury, providing a conjunction well worth watching through binoculars.

Mars sets about midnight throughout January, as eastern quadrature with the sun occurs on the 8th. Mars is now moving rapidly eastward in Pisces, and fades to magnitude +0.6 by midmonth, when it presents a disk 7″.9 in diameter—too tiny for telescopes of small and medium size to show appreciable detail.

Jupiter may be seen rising in the east about 10 p.m. Preceding its opposition in March, the largest planet begins retrograde motion on January 17th, about 2° west of Eta Virginis, and shining at magnitude −1.8. The equatorial diameter of Jupiter's disk is 39″.8 on that date.

Saturn is in the morning sky in January, visible for about two hours before sunrise. It is moving eastward in Ophiuchus about 6° north of Antares, and is about half a magnitude brighter than this red star.

Uranus may be seen throughout the night this month, as opposition with the sun occurs on the 25th. Now in retrograde motion, this 6th-magnitude planet will be midway between Theta and Eta Cancri at the end of January.

Neptune comes to western quadrature with the sun on the 22nd and is therefore visible only in the morning hours. This makes a total of six planets now in the dawn sky. Neptune is about 10° east of Spica, in eastern Virgo, at 14ʰ 03ᵐ.3, −10° 41′ (1950) on the 15th.

E. O.

JANUARY METEORS

A moonless night will favor the Quadrantid shower in the early hours of the morning of January 3rd. The moon sets about 6:30 p.m. on the evening of the 2nd. The shower is of very short duration, but with favorable conditions the total rate may reach 35 meteors per hour. These medium-speed meteors have their radiant in northern Bootes, at 15ʰ 24ᵐ, +50°.

E. O.

MOON PHASES AND DISTANCE

New moon	January 1,	2:13
First quarter	January 9,	7:06
Full moon	January 16,	6:21
Last quarter	January 22,	21:48
New moon	January 30,	21:24
First quarter	February 7,	23:23

	January	Distance	Diameter
Apogee	4, 8ʰ	252,500 mi.	29′ 25″
Perigee	16, 22ʰ	222,000 mi.	33′ 26″
Apogee	31, 14ʰ	252,700 mi.	29′ 23″
	February		
Perigee	14, 11ʰ	221,500 mi.	33′ 31″

SUNSPOT NUMBERS

October 1, 154, 170; **2,** 184, 183; **3,** 207, 192; **4,** 197, 195; **5,** 140, 192; **6,** 142, 160; **7,** 163, 160; **8,** 150, 189; **9,** 139, 198; **10,** 160, 189; **11,** 143, 166; **12,** 159, 175; **13,** 133, 170; **14,** 115, 121; **15,** 94, 108; **16,** 100, 104; **17,** 89, 90; **18,** 95, 106; **19,** 104, 126; **20,** 113, 145; **21,** 125, 150; **22,** 162, 155; **23,** 134, 126; **24,** 124, 167; **25,** 128, 173; **26,** 143, 160; **27,** 124, 154; **28,** 133, 162; **29,** 157, 187; **30,** 164, 216; **31,** 162, 195. Means for October: 139.9 American, 160.8 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by Dr. Sarah J. Hill from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

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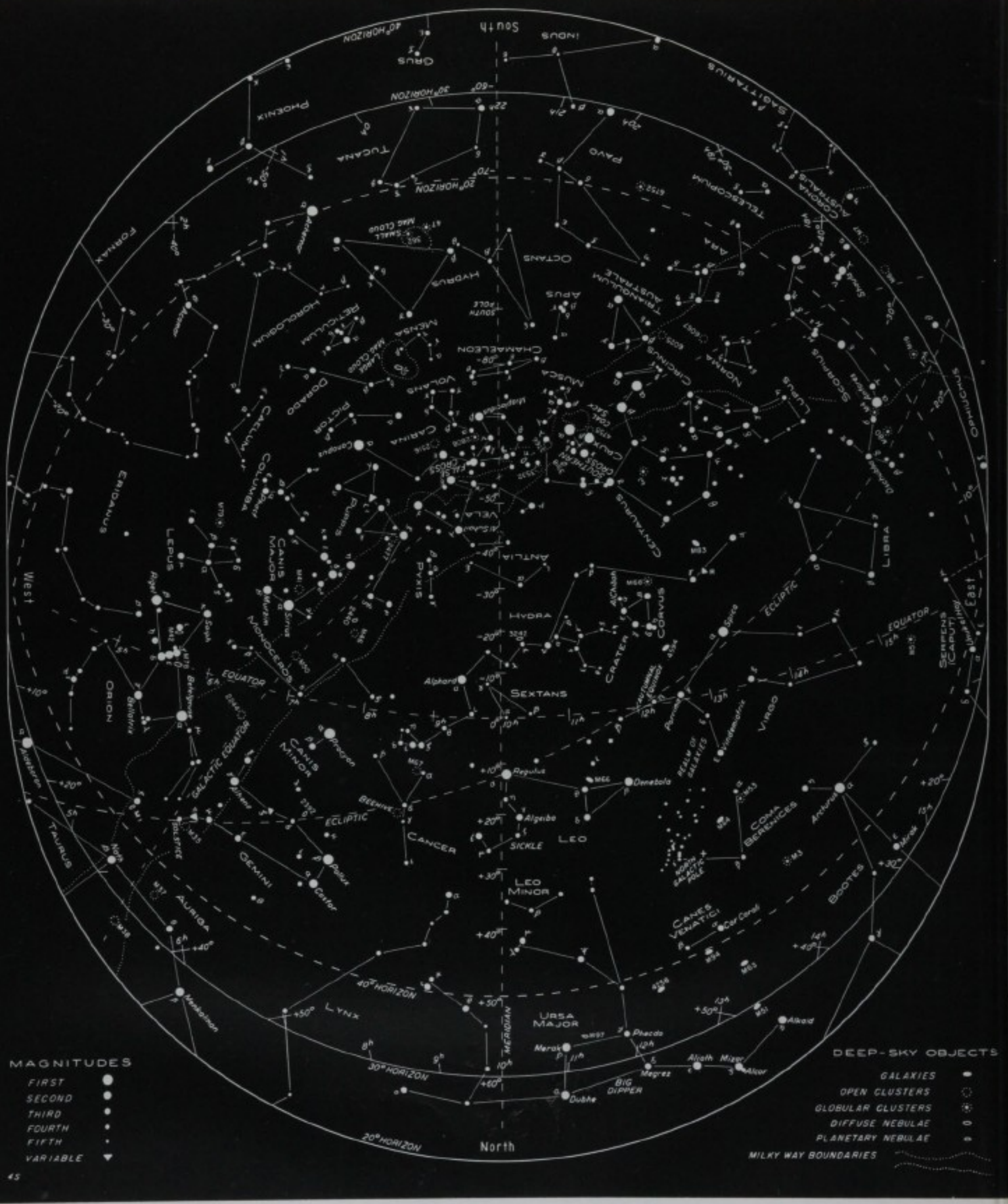

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SOUTHERN STARS

The sky as seen from latitudes 20° to 40° south, at 11 p.m. and 10 p.m., local time, on the 7th and 23rd of March, respectively; also at 9 p.m. and 8 p.m. on April 7th and 23rd. For other dates, add or subtract ½ hour per week.

Omega Centauri, a globular cluster nearly as bright as a 4th-magnitude star, is easily seen by the unaided eye as it ascends to a position very high in the sky. Norton describes it as looking like a tailless comet; it is 30 minutes of arc in diameter, a glorious telescopic sight.

STARS FOR JANUARY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of January, respectively; also at 7 p.m. and 6 p.m. on February 6th and 21st. For other dates, add or subtract ½ hour per week.

Seven 1st-magnitude stars dominate the winter sky, and they range in color from red Betelgeuse to bluish Rigel, both in Orion. Look for the prominent winter triangle, formed by Sirius, Procyon, and Betelgeuse. The last two and Pollux form another large triangle.

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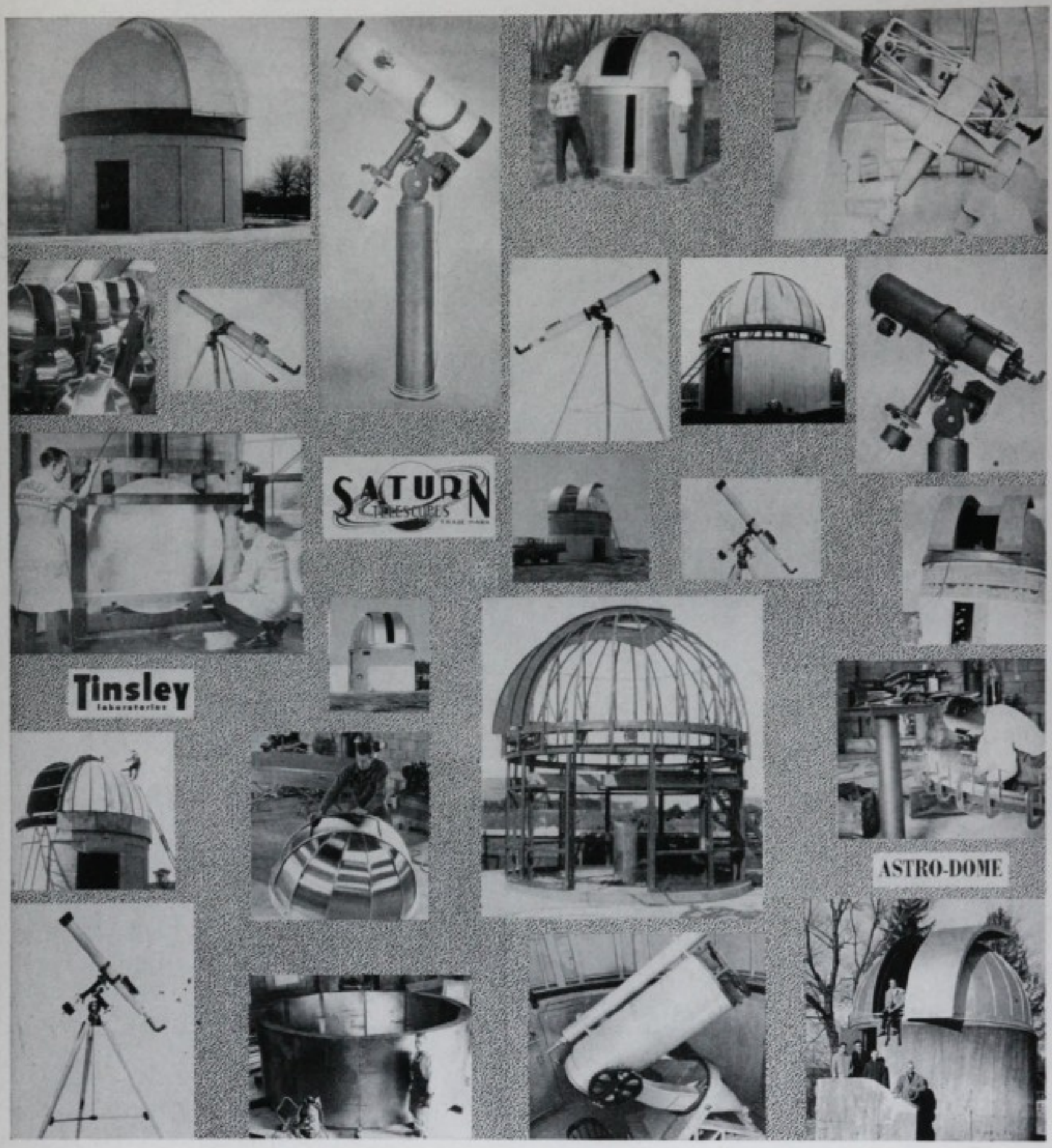

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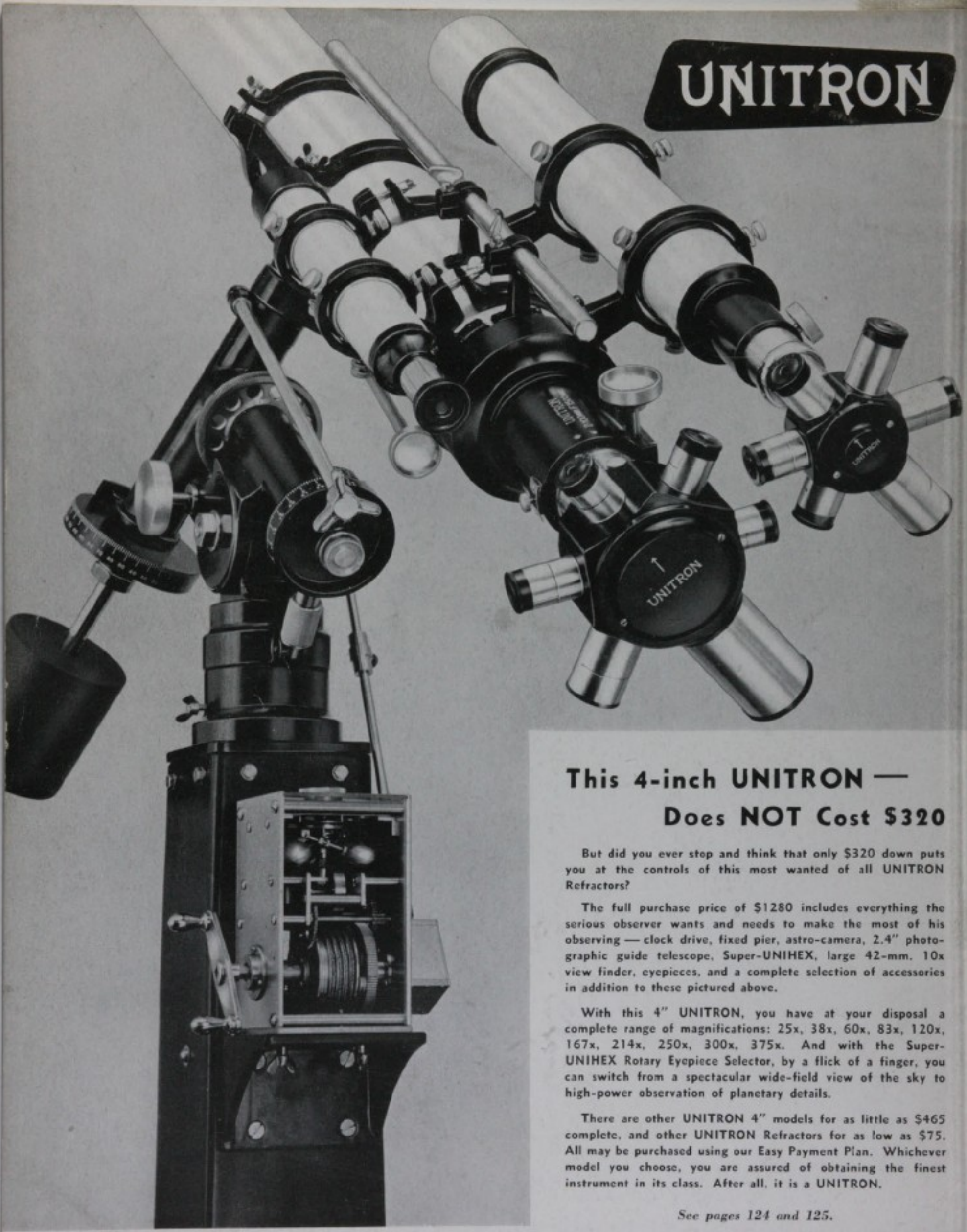

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